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BILGE WATER SURVEY CF SHIPS JANUARY TO MARCH 1999

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TECHNICAL MEMORANDUM

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Abstract

The results of the characterization of 40 bilge samples from CF ships are reported. The characterization included analysis of the pH, dissolved metal content, total suspended solids and total oil and grease in the aqueous phase and identification of the major components of the organic phase of the bilge samples. Eight samples exceeded the limit for dissolved cadmium and nine samples exceeded the limit for dissolved zinc. Five samples exceeded the limit for total suspended solids. The major components of the organic phase of the bilge samples were 3-GP-11 naval distillate fuel and lubricating oils. Five samples, that showed evidence of emulsification, were analysed for surfactants. All samples contained less than 30 parts per million anionic surfactant.

Résumé

Les résultats de la caractérisation de 40 échantillons provenant du fond de cale de navires des FC sont présentés. La caractérisation comprend la mesure du pH, de la teneur en métaux dissous, de la quantité totale de solides en suspension et de la quantité totale de graisse et de pétrole de la phase aqueuse, et l'identification des principaux composés présents dans la phase organique des échantillons de fond de cale. Huit échantillons ont présenté une teneur en cadmium dissous excédant la limite, neuf une teneur en zinc dissous excédant la limite et cinq une teneur en solides en suspension excédant la limite. Les principaux composés présents dans la phase organique des échantillons de fond de cale sont le mazout léger naval 3-G-11 et des huiles lubrifiantes. L'analyse de surfactants a été réalisée sur cinq échantillons présentant des traces d'émulsification. Ces échantillons contenaient tous moins de 30 parties par million de surfactant anionique.

Executive Summary

DREA TM/1999-102

Bilge Water Survey CF Ships, January to March 1999

by

Gary C. Fisher, John A. Hiltz, Matthew Frizzle and Francis Borden

In this report, the results of a survey of bilge water from several CF Ships and auxiliary vessels are reported. Forty bilge spaces from fourteen different vessels were sampled and analyzed. The ships sampled included the HMCS PRESERVER, HMCS HALIFAX, CFAV ENDEAVOUR, HMCS KINGSTON, HMCS ANTICOSTI, HMCS MONCTON, HMCS ONONDAGA, CFAV FIREBIRD, CFAV PARKSVILLE, and the De-magnetization and Wheeler barges. The goal of this survey was to characterize the contents, that is, determine the chemical composition of the aqueous and organic fractions, of bilge samples from a number of CF vessels.

The composition of the organic portion of the bilge from the various classes of ships was, in general, consistent with the fuels and lubricants used in the machinery and equipment in that space. Thus, no significance difference in bilge quality or composition was detected on the basis of ship class. A better predictor of bilge composition was the space itself.

The aqueous portion of the bilge samples contained evidence of sea water ingress and corrosion of bilge space materials. Ethylene glycol (1,2-ethanediol) was found in two bilge samples and five bilge samples contained small concentrations of surfactants. Also, two samples were found to contain concentrations of dissolved zinc and cadmium that exceeds the maximum limit for disposal via municipal sewer.

This work was funded by Formation Environment. The results will be used to assess the viability of establishing a shore-based facility to receive and treat bilge from CF ships.

INTRODUCTION

Canadian Forces ships and submarines produce bilge, generally a two phase fluid consisting of organic and aqueous layers, during operations. When the vessel returns from its deployment this fluid is pumped from the bilge spaces and disposed by a contractor. The disposal of bilge is costly as a result of the large volumes produced.

The obvious approach to reducing costs is to reduce the volume of bilge that must be removed by contractors. This can be accomplished in two ways.

The first is to separate the aqueous and organic phases and dispose of the water overboard. Present laws require that water dumped from a ship into the ocean contain less than 15 ppm hydrocarbons and in Canadian harbours and coastal waters less than 5 ppm hydrocarbons. These are stringent requirements. In an attempt to meet these requirements, membrane filtration units are being installed on Canadian Patrol Frigates. If these units are successful, they will make a significant contribution to reduce of bilge wastes.

The second is to recover and use as much of the organic layer as possible from the remaining bilge. This might involve pumping the bilge to a shore based oily waste treatment plant where it would be processed. This waste could then be burned in a heating plant or possibly processed to recover fuel and oil. But is this the most environmentally friendly and cost effective way to handle this waste?

The first step in answering this question is to determine the composition of bilge fluids. The hydrocarbon portion of bilge fluids should be representative of the bilge fluid that would remain after processing to remove water.

In this report, the results of a survey of bilge water from several CF Ships and auxiliary vessels are reported. Forty bilge spaces from fourteen different vessels were sampled and analyzed. The ships sampled included the HMCS PRESERVER, HMCS HALIFAX, CFAV ENDEAVOUR, HMCS KINGSTON, HMCS ANTICOSTI, HMCS MONCTON,

HMCS ONONDAGA, CFAV FIREBIRD, CFAV PARKSVILLE, and the Demagnetization and Wheeler barges. The goal of this survey was to characterize the contents, that is, determine the chemical composition of the aqueous and organic fractions, of bilge samples from a number of CF vessels.

EXPERIMENTAL

Sampling

All bilge water samples were taken with Coliwasa Sampling Tubes. Theses tubes are designed to collect a core type sample of liquid from a tank. A sample is taken by placing the open tube in the tank to be sampled. A teflon plunger at the bottom of the tube is retracted to capture the sample. Bilge samples were collected in acid washed (30% hydrochloric acid) 1L high density polyethylene (HDPE) bottles prior to sample preparation and analysis. The identity and dates of the bilge spaces sampled are listed in Table 1. This Table utilizes a bilge space naming scheme that is explained in Appendix 1.

Sample Preparation and Testing

A flow chart for sample preparation and testing is shown in Scheme 1. The first step in the analysis of the bilge water samples was separation and measurement of the volumes of the aqueous and organic phases. Each phase was examined separately and, where appropriate, stored at 4°C in suitably sized acid-washed HDPE containers.

Organic Phase

Gas chromatography/mass spectrometry (GC/MS)

Gas chromatography/mass spectrometry was used to analyse the organic fraction of the bilge samples. The samples were diluted 1 in 250 in hexane and 1μL of the resulting solution injected in the modified splitless mode. A 30 m long x 0.25 mm inside diameter

DB-5 (5%phenyl-95% methyl silicone) with 5 μm thick stationary phase was used for all chromatographic separations.

The temperature program for the gas chromatograph oven consisted of holding the temperature at 40°C for 5 min, ramping the temperature to 150°C at a rate of 8°C/min, and then ramping the temperature to 300°C at a rate of 10°C/min to 300°C. The temperature was then held at 300°C for 15 min. The carrier gas was helium (flow rate 1 mL/min at 110°C).

Two GC/MS systems were used; a Finnigan ITD (ion trap detection) GC/MS and a Fisons Platform 800 (quadrupole) GC/MS. Mass spectra were collected in the full scan mode (1 scan/sec). The mass range for the ITD was 50 to 650 atomic mass units (amu)) and 25 to 500 amu on the quadrupole instrument.

Aqueous Phase

A portion of 100 milliliters (mL) of the aqueous phase of each sample was removed and used to determine pH, Total Suspended Solids and dissolved metal content. The pH was first measured on this portion using an Orion 720 pH meter with a two-point calibration. Afterwards, Total Suspended Solids (TSS) was determined in accordance with APHA Standard Method 2540D (1). Undiluted filtrate from the TSS test was then acidified with nitric acid to approximately pH 2 and stored at 4°C for later determination of dissolved metal content.

The composition and physical characteristics of aqueous samples can change during storage due to oxidative processes, thermal factors, etc. It is therefore important to measure some parameters as soon as practical after collecting the sample and to promptly treat the sample to prevent alteration. Thus, the phase separation step and measurement of pH and TSS and acidification of the aqueous phase were all done within two hours of sample collection.

The remainder of the aqueous phase, that is, the portion not used for pH or TSS determination, was acidified within two hours of sample collection with nitric acid to a pH of approximately 2 and stored at 4°C in acid-washed HDPE containers. This portion was used to determine Total Oil and Grease (APHA Standard Method 5520B) (1), surfactant content (APHA Standard Methods 5540B and 5540C) (1), Chemical Oxygen Demand (APHA Standard Method 5220B) (1), and total metal content. As well, dissolved organics in this aqueous phase were characterized by solid phase microextraction.

For Total Oil and Grease (TOG) a 100 mL portion was extracted with a mixture of hexane and methyl t-butyl ether (80/20 v/v) and the solvent removed by distillation on a water bath. TOG was reported in milligrams oil and grease per liter of water.

For surfactant content a 100 mL portion of the acidified aqueous phase was diluted to 1 L with distilled water and 5 gm $NaHCO_3$ and 100 gm NaCl added. This mixture is placed in the sublation apparatus, as described in APHA Standard Method 5440B (1), and covered with 100 mL ethyl acetate. Nitrogen is then bubbled through the sample at a rate of 1 L/min. Surfactants in the sample are concentrated at the surface of the gas bubbles and are therefore carried into the ethyl acetate layer where they dissolve. The ethyl acetate solution was then concentrated and the residue dissolved in methanol, diluted with water and the methanol distilled off. The aqueous solution was transferred to a separatory funnel and made up to 100mL with distilled water. This solution was then analyzed according to APHA Standard Method 5440C (1) for anionic surfactant content.

Surfactants exist in two types: nonionic and ionic. In North America ionic surfactants account for approximately 2/3 of total surfactant production. As there is no known test specific for nonionic surfactants the results of the ionic surfactant quantitation could be used to estimate total surfactant content. Further, ionic surfactants can be of two varieties: anionic or cationic. Cationic surfactants are used primarily as disinfectants, fabric softeners and as solubilizers in cosmetics. It was therefore anticipated that little, if any cationic surfactants would be found in CF bilge samples and the surfactant sample was therefore tested solely for the presence of anionic surfactants.

The anionic surfactant quantitation involves the use of methylene blue, which forms ion-pairing complexes with anionic compounds. An excess of a methylene blue solution was added to the solution prepared above and the resulting methylene blue/anionic surfactant ino pairs extracted into chloroform. The absorbance at 652 nm of the chloroform extract was measured using a Hewlett-Packard Model 8453 ultraviolet-visible spectrometer. Anionic surfactant concentrations were determined from a dodecyl benzene sulfonic acid sodium salt calibration curve prepared in the same manner.

The standard COD test consists of refluxing for two hours a mixture of 50 mL sample, 75 mL sulfuric acid/silver sulfate reagent, 1 gm mercuric sulfate and 25 mL 0.0417M potassium dichromate. The refluxed solution is then titrated with standardized ferrous ammonium sulfate solution. COD is calculated, in milligrams oxygen per liter by the following formula:

$$COD = \frac{A \times M \times 8000}{mL \text{ sample}}$$

where A is mL of ferrous ammonium sulfate required and M is that solution's molarity.

Total and dissolved metal content were both determined by inductively coupled plasma – atomic emission spectrometry (ICP-AES) using a Varian Liberty Series II spectrometer. All analyses were conducted using a plasma gas flow rate of 15 L/min and an auxiliary gas flow rate of 1.5 L/min. Sample introduction was via a peristaltic pump through a nebulizer operating at 180 kilopascals. Elemental signals were detected by a photomultiplier tube operating at 650 volts and using a 3 second interval. Signals were quantitated against 10 part per million (ppm) standards prepared from certified stock solutions and a distilled water blank signal calculated using polynomial plotted background correction. Specific data for the 16 measured elements is included in Appendix 2.

Solid phase microextraction (SPME) was used to characterize dissolved organics in the aqueous layer. The SPME apparatus consisted of a 1cm long fibre with a 30 mm thick

poly(dimethylsiloxane) coating. Sampling was conducted by immersing the fibre into a vigorously stirred sample (4 mL) for 15min at room temperature (~20-22 C).

The extracted sample was thermally desorbed in the injector of the GC and analysed with the Fisons GC/MS.

RESULTS AND DISCUSSION

Bilge Analysis Results

The following section details the results of the various analyses conducted on the collected bilge samples. The data generated in this report will be used to assess further evaluation of potential methods to reduce costs associated with bilge disposal. As discussed earlier, two possible methods are in-ship separation of hydrocarbon/aqueous phases followed by jettison of the aqueous phase, and on-shore treatment of bilge to collect and re-use the hydrocarbon phase and disposal of the aqueous phase by municipal sewer. Thus, discussion of the data generated here must include recognition of any current or future regulations governing ocean/harbour and municipal sewer disposal of bilge.

Current regulations for ocean dumping of waters impose limits of 15 ppm hydrocarbon content. This limit falls to 5 ppm in harbour or coastal waters. Municipal sewer regulations impose numerous limits on the physical and chemical make-up of waste water. These limits are used throughout the remainder of this report when discussing bilge composition. The limits discussed are those for the Regional Municipality of Halifax, as detailed in By-Law W-100 (2).

Phase Composition

The percent by volume aqueous and organic phases in the forty bilge samples are shown in Table 1. The volume of the aqueous phase in the samples varied from 0 to 100% and

the average for the forty samples was 83%. Half of the samples had an aqueous layer of greater than 94% by volume.

Characterization of Organic Phase

Gas Chromatography/Mass Spectrometry

To aid in the identification of the constituents of the organic phase of the bilge samples, samples of fluids commonly used on CF vessels were also analysed. Chromatograms of samples of 3-GP-11 naval distillate fuel, NATO F44 aviation turbine fuel, MIL-L-9000 diesel lubricating oil, and MIL-L-23699 are shown in Figures 1 to 4.

The bilge samples analysed are listed in Table 2 along with the major constituents of the organic phase. These represent 20 of the 31 bilge samples that had an organic phase. The chromatograms for these samples (Figures 5 - 24) were compared with those shown in Figures 1 to 4 and the comparison used to indicate the major constituents of the organic phase. No effort was made to differentiate between lubricating oil and hydraulic fluid. These are listed as 'oil'.

Three of the bilge samples, from the air conditioning space HMCS ATHABASKAN and the motor and the forward machinery rooms of HMCS KINGSTON, contained only oil. Two of the bilge samples, from the forward engine room HMCS ST. JOHN'S and the YTL 594, contained approximately equal amounts of naval distillate fuel and oil. The remainder of the bilge samples contained either naval distillate fuel or naval distillate fuel with a small amount of oil.

Characterization of Organic Material in the Aqueous Phase

Solid phase microextraction followed by GC/MS analysis was used to characterize dissolved organic material in the aqueous phase of the bilge samples. To aid in the identification of the organic constituents, samples of fuels, lubricants, and hydraulic fluids used on CF ships were also analysed by GC/MS. Chromatograms of samples 3-

GP-11 naval distillate fuel, NATO F44 aviation turbine fuel, MIL-L-9000 diesel lubricating oil, 3-GP-36 grade 32 hydraulic fluid, 3-GP-36 grade 68 hydraulic fluid, 3-GP-44 refrigerant compressor lubricating oil, 3-GP-357 steam turbine lubricating oil, MIL-L-23699 turbine engine synthetic lubricating oil are shown in Figures 25 to 32.

The bilge samples analysed are listed in Table 3 and the chromatograms are shown in Figure 33 to 47. The major organic constituents of the bilge samples are listed in Table 3. In some instances it was difficult to differentiate between hydrocarbon based lubricating oils and therefore they are listed simply as lubricating oil.

The organic constituents in the aqueous layer were similar to those found in the organic layer of the bilge samples. 3-GP-11 naval distillate fuel and lubricating oils were the major dissolved organic constituents. However, ethylene glycol (1,2-ethanediol) was found in the bilge samples from the engine room of HMCS ONONDAGA and the after pump room of HMCS PRESERVER. 3-GP-44 refrigerant compressor lubricating oils was the major constituent of the bilge sample from the #1 air conditioning space of HMCS ATHABASKAN.

Comparison of Organic Phase and Extracted Organics from the Aqueous Phase

The chromatograms of the organic phase and the organics extracted from the aqueous phase of the bilge sample from the engine room of HMCS ATHABASKAN are shown in Figures 8 and 33 respectively. The major organic constituent in the organic and aqueous phases is 3-GP-11 fuel. However, there is oil in the extracted organics from the aqueous that is not seen in the chromatogram of the organic phase. This could be due to a number of factors including the amount of time the oil and fuel had been in the bilge and the polarity of the oil. For instance if the oil was partially oxidized it would be more polar and this could increase its solubility in the aqueous phase.

The chromatograms of the organic phase and the organics extracted from the aqueous phase of the bilge sample from the #1 air conditioning space HMCS ATHABASKAN are

shown in Figures 9 and 34 respectively. In this instance the constituents of the samples are the same, lubricating oil similar to 3-GP-44 refrigerant compressor lubricating oil.

The chromatograms of the organic phase and the organics extracted from the aqueous phase of the bilge sample from the engine room of HMCS HALIFAX are shown in Figures 11 and 35 respectively. As was found for the engine room bilge sample from HMCS ATHABASKAN, there is a significant difference in the relative amounts of 3-GP-11 naval distillate fuel and oil in the two samples. The organic layer was primarily 3-GP-11 with a small amount of oil while the extracted organics from the aqueous layer were primarily oil with a small amount of 3-GP-11. This could indicate that the fuel had not been in the bilge long enough to dissolve in the aqueous layer.

On the basis of these samples it can be concluded that it is not always possible to comment on the relative proportions of the organic constituents dissolved in the aqueous layer based on an analysis of the organic phase of a bilge sample. Similarly, it is not always possible to comment on relative proportion of the constituents of the organic phase based on an SPME analysis of the aqueous phase.

Characterization of Aqueous Phase

pH

The pH results of the 37 samples are shown in Table 1. pH values ranged from 3.48 to 9.43. All but one sample (pH 3.48) had pH values between 4 and 10. Current ocean dumping and municipal sewer regulations do not impose any limits on the pH of effluent.

Total Suspended Solids (TSS)

The results of the total suspended solids analyses are listed in Table 1. Total suspended solids ranged from 10 ppm to 604 ppm (w/v). The average and median values of TSS were 126 ppm and 54.5 ppm.

Municipal sewer regulations impose a maximum limit of 300 ppm TSS. Five of the evaluated bilge spaces exceeded this limit. Three of these spaces were on HMCS KINGSTON, one on HMCS PRESERVER, and one on HMCS ANTICOSTI. The failure of some bilge spaces to meet this limit indicates that some form of control over solid content would be required in a shore-based facility designed to handle bilge waters.

Total Oil and Grease (TOG)

The results of the TOG analyses are shown in Table 1. TOG in the aqueous layer of the bilge samples ranged from 4 ppm to 3687 ppm (w/v). The average and median values of TOG were 709 ppm and 254 ppm respectively.

Limits on hydrocarbon content of waste water range from 5 ppm for Canadian harbours and coastal waters to 100 ppm for municipal sewers. Therefore adequate separation of hydrocarbon phases must be completed before either option, ocean disposal or shore-based treatment, could be considered. The membrane filtration technology currently being evaluated on the CPFs could prove capable of producing waters that meet these limits. It is anticipated that similar measures will be required for any future shore-based facility.

Surfactant Analysis

Surfactact analysis was carried out on the five bilge samples listed in Table 4. These samples were selected for analysis as they showed evidence of an emulsified layer and therefore the presence of surfactants.

A calibration curve for surfactant concentration was prepared using the sodium salt of dodecylbenzene sulfonic acid. The curve is shown in Figure 48 and is linear over the concentration range between 0 µg/mL (ppm) and 200 µg/mL.

The results of the analysis on the five bilge samples are shown in Table 4. The concentration of surfactant ranged from 4 ppm to 26 ppm.

These relatively low concentrations of surfactant should be considered a positive result. Normally aliphatic and aromatic hydrocarbons, such as those found in the lubricants and fuels detected in these bilge samples, are essentially insoluble in water. However, the presence of surfactants greatly increases the solubility and reduces the effectiveness of any technique designed to separate hydrocarbons from water.

Chemical Oxygen Demand

The standard open reflux method for COD (APHA Standard Method 5220B) (1) was not applicable to the bilge samples due to interference by high chloride ion concentrations (see later discussion on metal content). An alternate method for highly saline waters was tried (3) but did not yield consistent results. An alternate procedure for COD in such waters (4) is available but was not tested due to lack of proper equipment. Thus, no evaluation of this parameter can be presented.

Metal Content

The results of the dissolved and total metal content analyses are presented in Tables 5 and 6 respectively, along with the corresponding maximum allowable limits for waters disposed via municipal sewer.

As can be seen, a number of exceedances occurred, particularly for cadmium and zinc content. The cause of the zinc exceedances is likely the presence of zinc anodes or galvanized steel in some of the bilge spaces. The cause of the cadmium exceedances is not known.

It is apparent therefore that some method of removing metal content will be necessary for a shore-based bilge treatment facility. It is possible that treatment similar to that employed by the Waste Water Treatment Facility in Fleet Maintenance Facility Cape Scott would be effective in this matter.

The results of the metal content analysis also indicate that many samples contained significant quantities of sodium, potassium, magnesium and calcium. This suggests that many of the bilge spaces contained appreciable amounts of seawater. While this is hardly a surprising result, it did have the effect of rendering COD determination difficult due the presence of excessive chloride ions. The presence of seawater may also make hydrocarbon and metal ion separation easier in a shore-based facility as high ionic strength facilitates both separations.

SUMMARY AND CONCLUSIONS

The composition of the organic portion of the bilge from the various classes of ships was, in general, consistent with the fuels and lubricants used in the machinery and equipment in that space. For instance the organic phase ER and AMR bilge samples, regardless of class of ship, consisted of 3-GP-11 naval distillate fuel, lubricating oil, or a mixture of the two as major constituents.

To re-iterate, no significance difference in bilge quality or composition was detected on the basis of ship class. A better predictor of bilge composition was the space itself.

Ethylene glycol (1,2-ethanediol) was found in two bilge samples (HMCS ONONDAGA engine room bilge and HMCS PRESERVER after pump room bilge). As ethylene glycol is water soluble, it will increase the chemical oxygen demand of the aqueous portion of the bilge.

Five bilge samples contained surfactants and the concentration was less than 30 ppm for all five samples. This is a positive result, as surfactants will complicate separation of the aqueous and organic phases of bilge samples.

Suspended solids exceeded the limit of 300 ppm in five bilge spaces; three on HMCS KINGSTON, one on HMCS PRESERVER, and one on HMCS ANTICOSTI. Treatment

of bilge water that exceeds this limit will require a filtration step prior to clean up and discharge.

The limits for dissolved zinc (3 ppm) and cadmium (0.01 ppm) were exceeded in 8 and 9 samples respectively. This indicates that bilge water will have to be processed to ensure that dissolved metals limits are not exceeded. One approach would be to process the aqueous phase of bilge at the FMF Cape Scott waste water treatment facility. If this is not feasible or if a separate facility is planned, then it is recommended that consultants be hired to aid in the design of the facility.

It should be noted that additional samples exceeded the municipal sewer disposal limits for both zinc and cadmium, as well as several for copper and lead. However, the fact that these additional samples met the limit when tested for dissolved metals indicates that simple filtration would have been sufficient as treatment. The exceedances found when testing for dissolved metal content are considered more significant as they impose additional treatment steps beyond simple filtration.

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3. E. R. Burns and C. Marshall, "Correction for Chloride Interferences in the Chemical Oxygen Demand Test", Journal of Water Pollution Control, 37, 1716 (1965).

4. Baumann. J. Frank, "Dichromate Reflux Chemical Oxygen Demand A Proposed Method for Chloride Correction in Highly Saline Wastes". Anal. Chem., Vol. 46, 1336-1338 (1974).

Table 1 – Percent water, percent organic, pH of the water layer, total suspended solids (TSS) in the water layer, and total oil and grease in the water layer of forty bilge samples. The hull number and bilge are as listed in Appendix 1. The limits for TSS and TOG are 300 ppm and 100 ppm respectively (2). pH is not regulated (2).

Sample No.	Hull Number	Bilge	Date	% Water	% Organic	pH	TSS (ppm)	TOG (ppm)
1	700	Aft.MR	28 Jan 99	100	0	9.43	470	1600
2	700	Fwd.MR	28 Jan	96	4	9.37	500	1800
3	700	MoR	28 Jan	70	30	7.20	290	130
4	700	ZR	28 Jan	94	6	7.44	600	180
5	708	FMR	28 Jan	92	8	6.14	15	<1
6	708	AMR	01 Feb	94	6	6.75	25	28
7	Onon	AMS	08 Feb	95	5	6.86	110	10
8	Onon	ACS	08 Feb	100	0	7.19	94	1800
9	Onon	DS0	08 Feb	100	0	6.70	39	
10	Onon	ER	08 Feb	39	61	8.80	160	4
11	510	FERab	16 Feb	100	0	5.89	13	530
12	510	FERob	16 Feb	100	0	6.91	22	75
13	510	FERmb	16 Feb	92	8	6.22	28	
14	510	ATRp	16 Feb	97	3	7.18	42	770
15	510	ATRs	16 Feb	98	2	6.91	95	1500
16	510	APR	16 Feb	82	18	6.57	31	2500
17	510	BT	17 Feb	100	0	6.55	390	3700
18	510	FPR	17 Feb	1	99			
19	171	Ermi	23 Feb	100	0	6.29	59	360
20	561	St.C	23 Feb	0	100			
21	561	ERmb	23 Feb	100	0	9.27	150	
22	YDG2		23 Feb	81	19	7.88	250	500
23	YTL594		25 Feb	82	18	8.61	50	370
24	YRG62		25 Feb	95	5	7.57	92	250
25	330	AER	07 Jan	77	23	6.25	43	
26	340	AER	07 Jan	71	29	9.12	72	
27	340	FER	07 Jan	69	31	8.88	29	
28	340	AAMR	07 Jan	2	98			
29	340	FAMR	07 Jan	94	6	3.48	13	
30	280	ER	21 Jan	98	2	8.63	31	130
31	280	GR	21 Jan	94	6	8.50	66	
32	280	SULL	21 Jan	73	27	6.24	9	40
33	280	AMR	21 Jan	98	2	6.41	11	20
34	280	TF	21 Jan	100	0	6.30	27	
35	330	OWC	22 Jan	94	6	7.13	70	<1
36	330	FAMR	22 Jan	100	0	7.34	20	<1
37	330	AER	22 Jan	93	7	7.64	17	21
38	110	bilge	05 Mar	77	23	7.80	480	
39	282	#1ACS	11 Mar	100	0	6.77	130	150
40	282	ER	11 Mar	78	22	6.03		<1

Table 2 – Composition of the organic layer of 20 bilge as determined by GC/MS analysis and comparison to standard fuel and lubricant samples.

Chromatogram	Sample	Date	Composition
Figure 5	280ER	21 Jan 99	3-GP-11 Naval distillate fuel and small amount of oil.
Figure 6	280AMR	21 Jan 99	3-GP-11 Naval distillate fuel
Figure 7	280Sull	21 Jan 99	3-GP-11 Naval distillate fuel
Figure 8	282ER	11 Mar 99	3-GP-11 Naval distillate fuel
Figure 9	282#1ACS	11 Mar 99	Oil
Figure 10	330OWC	22 Jan 99	3-GP-11 Naval distillate fuel and small amount of oil
Figure 11	330AER	22 Jan 99	3-GP-11 Naval distillate fuel and small amount of oil
Figure 12	340FAMR	07 Jan 99	3-GP-11 Naval distillate fuel and small amount of oil
Figure 13	340AER	07 Jan 99	3-GP-11 Naval distillate fuel and small amount of oil
Figure 14	340AAMR	07 Jan 99	3-GP-11 Naval distillate fuel and small amount of oil
Figure 15	340FER	07 Jan 99	~50% 3-GP-11 Naval distillate fuel and ~50% oil.
Figure 16	510APR	16 Feb 99	3-GP-11 Naval distillate fuel
Figure 17	700MoR	28 Jan 99	Oil
Figure 18	700FMR	28 Jan 99	Oil
Figure 19	708FMR	01 Feb 99	3-GP-11 Naval distillate fuel
Figure 20	708AMR	01 Feb 99	3-GP-11 Naval distillate fuel
Figure 21	YDG2-	23 Feb 99	3-GP-11 Naval distillate fuel
Figure 22	YRG62	25 Feb 99	3-GP-11 Naval distillate fuel
Figure 23	YTL 594	25 Feb 99	~60% Oil and ~40% 3-GP-11 Naval distillate fuel
Figure 24	110FER	05 Mar	3-GP-11 Naval distillate fuel

Table 3 – Solid phase microextraction GC/MS results for organics in the aqueous layer of bilge samples.

Chromatogram	Sample	Date	Composition
Figure 33	282ER	11 Mar 99	3-GP-11 naval distillate fuel and 3-GP-357
Figure 34	282#1ACS	11 Mar 99	3-GP-44
Figure 35	330AER	22 Jan 99	Lubricating oil and trace 3-GP-11 naval distillate fuel
Figure 36	510FER(ab)	16 Feb 99	3-GP-357
Figure 37	510FER(ob)	16 Feb 99	Trace of aromatic hydrocarbons
Figure 38	510APR	16 Feb 99	3-GP-11 naval distillate fuel, ethylene glycol and acetic acid
Figure 39	700AMR	28 Jan 99	3-GP-11 naval distillate fuel and heavier lubricating oil
Figure 40	700ER	28 Jan 99	Trace organic
Figure 41	708AMR	1 Feb 99	Trace organic
Figure 42	OnonER	8 Feb 99	Ethylene glycol
Figure 43	YDG2	23 Feb 99	3-GP-11 naval distillate fuel
Figure 44	YRG62	25 Feb 99	3-GP-11 naval distillate fuel
Figure 45	YTL594	25 Jan 99	Oxidized organics and lubricating oil
Figure 46	561ER	23 Feb 99	3-GP-11 naval distillate fuel and MIL-L-9000 lubricating oil
Figure 47	171mid	22 Feb 99	Lubricating oil

Table 4. Results of surfactant analysis. The values are reported as equivalents of linear alkylbenzene sulfonate (Dodecylbenzene Sulfonic Acid, Sodium Salt; molecular weight 348.48) and were calculated using the calibration curve shown in Figure 48.

Hull Number	Bilge	Date	Sample Volume (mL)	Absorbance	Surfactant Concentration (mg/L)
700	FMR	28 Jan 99	10.0	0.546	23.10
510	FERmb	16 Feb 99	20.0	0.272	5.28
110	FER	05 Mar 99	15.0	0.653	18.68
282	#1ACS	11 Mar 99	20.0	0.298	5.87
280	SULL	21 Jan 99	20.0	0.209	3.85

TABLE 5: Dissolved metal content in aqueous portion of bilge. All values are in ppm. Concentrations which were found to exceed the municipal sewer discharge maximum allowable limit (2) are highlighted by bold type.

SHIP	BILGE	Al	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Si	Sn	Ti	Zn
Limit (Ref 2)		*50*	*NA*	*0.01*	*4.0*	*1.0*	*50*	*NA*	*NA*	*5.0*	*NA*	*2.0*	*2.0*	*NA*	*5.0*	*5.0*	*3.0*
171	ER(m)	0.02	130	**0.88**	<0.004	0.24	0.15	130	410	0.36	3700	0.09	0.7	0.52	<0.1	<0.01	4.3
510	FER(ab)	0.05	180	0.005	<0.004	0.06	0.05	210	590	0.06	5600	0.03	0.2	0.23	<0.1	<0.01	2.5
510	BT	0.02	260	**0.83**	<0.004	0.07	0.03	330	850	0.16	8600	0.05	1.3	0.25	<0.1	<0.01	6.3
510	APR	0.05	21	<0.003	<0.004	0.02	3.2	16	58	0.10	440	0.08	0.2	0.95	<0.1	<0.01	1.4
510	FER(ob)	0.05	2.6	<0.003	<0.004	0.02	0.02	3.1	6.4	0.01	44	0.03	<0.1	0.08	<0.1	<0.01	0.11
510	ATR(s)	0.05	15	<0.003	<0.004	0.03	0.05	13	40	0.08	306	0.03	0.2	3.5	<0.1	<0.01	0.30
510	ATR(p)	0.02	22	<0.003	<0.004	0.03	2.9	24	46	0.24	360	0.18	0.1	1.1	<0.1	0.01	0.89
330	FAMR	0.09	210	**0.17**	<0.004	0.16	0.43	230	600	0.74	5600	0.61	0.9	0.80	<0.1	<0.01	1.6
330	OWC	<0.02	170	0.006	0.004	0.01	5.6	200	540	0.38	4700	0.43	0.0	0.42	<0.1	<0.01	1.4
330	AER	0.11	360	<0.003	<0.004	0.03	6.6	500	1300	0.54	13000	0.07	1.9	0.53	<0.1	<0.01	0.11
708	FMR	0.09	44	<0.003	<0.004	<0.01	<0.01	96	91	<0.01	1200	0.02	<0.1	0.25	<0.1	<0.01	0.02
708	AMR	0.64	22	<0.003	<0.004	0.04	1.0	7.0	22	0.07	160	0.01	0.1	1.0	<0.1	0.02	1.3
280	TF	<0.02	1.6	<0.003	<0.004	0.04	0.08	0.26	0.95	0.04	7.5	0.02	0.2	0.08	<0.1	<0.01	1.1
280	AMR	<0.02	290	**0.84**	0.004	0.05	0.02	370	980	0.43	9300	0.66	0.2	0.38	<0.1	<0.01	0.85
280	ER	<0.02	125	<0.003	<0.004	<0.01	0.04	140	410	0.20	3400	0.02	1.8	0.26	<0.1	<0.01	0.46
280	SULL	0.06	100	0.007	0.005	0.04	1.2	54	180	0.61	1400	0.10	0.2	0.68	<0.1	<0.01	0.39
280	GR	0.23	300	<0.003	0.01	0.01	1.7	410	1000	0.22	10000	0.03	0.6	0.06	1.6	<0.01	**38**
282	#1ACS	0.21	33	0.005	<0.004	0.17	0.03	31	100	0.09	1000	0.03	0.1	0.25	<0.1	<0.01	0.15
110	FER	0.09	220	0.003	0.004	0.43	0.43	380	710	0.36	7400	0.01	<0.1	3.9	<0.1	<0.01	1.2
700	ZR	0.20	26	0.008	0.004	0.06	0.70	6.7	13	0.10	51	0.02	0.2	1.6	<0.1	0.03	5.2
700	MR	0.10	130	0.003	0.008	0.09	0.53	150	380	0.39	3300	0.06	<0.1	0.69	<0.1	<0.01	17
700	AMR	0.06	37	0.004	0.02	0.10	0.67	18	37	0.08	970	0.06	<0.1	42	<0.1	<0.01	0.29
700	PMR	0.12	31	**0.010**	0.005	0.30	0.18	68	41	0.02	510	0.01	0.2	40	<0.1	<0.01	0.52
561	ER	0.08	16	<0.003	<0.004	<0.01	0.05	270	1000	0.15	6600	0.02	1.7	0.27	<0.1	0.02	0.05
Orion	AMS	<0.02	44	<0.003	<0.004	0.01	0.03	35	120	0.10	970	0.02	0.2	0.09	<0.1	<0.01	3.3
Orion	DS	0.06	21	**0.81**	<0.004	0.06	0.34	12	25	0.08	190	0.03	<0.1	0.69	<0.1	<0.01	**6.0**
Orion	ER	0.04	7.5	<0.003	0.01	<0.01	0.09	87	81	<0.01	2300	0.01	0.4	21	<0.1	<0.01	0.22
Orion	ACS	<0.02	270	**0.87**	0.004	0.09	0.06	340	870	0.18	9000	0.03	1.4	0.22	<0.1	<0.01	5.3
YRG62		<0.02	27	**0.84**	<0.004	0.02	1.5	22	75	2.2	680	0.04	0.1	0.31	<0.1	<0.01	**88**
YTL59		0.02	230	<0.003	<0.004	<0.01	0.03	410	1100	0.09	11000	0.02	1.6	0.10	<0.1	<0.01	0.23
YDG2		0.02	78	<0.003	0.005	<0.01	1.7	72	240	0.64	2500	<0.01	0.1	7.3	<0.1	<0.01	0.08

TABLE 6: Total metal content in aqueous portion of bilge. All values are in ppm. Concentrations which were found to exceed the municipal sewer discharge maximum allowable limit (2) are highlighted by bold type.

SHIP	BILGE	Al	Ca	Cd	Cr	Cu	Fe	K	Mg	Mn	Na	Ni	Pb	Si	Sn	Ti	Zn
Limit (Ref. 2)		*50*	*NA*	*0.01*	*4.0*	*1.0*	*50*	*NA*	*NA*	*5.0*	*NA*	*2.0*	*2.0*	*NA*	*5.0*	*5.0*	*3.0*
171	ER(m)	0.91	160	**0.898**	<0.004	0.83	3 9	170	510	0.45	4400	0.09	0.2	0.66	<0 1	<0.01	**6.9**
510	FER(eb)	0.04	220	0.007	<0 004	0.16	0 88	270	760	0 08	6900	0 03	1.1	0.21	<0 1	<0.01	3.3
510	BT	0 57	350	**0.85**	0.01	0.37	2 0	460	1200	0.24	12000	0 08	1.8	0.35	<0.1	<0.01	**9.6**
510	FER(mb)	<0.02	220	0.005	<0 004	0.13	0 68	260	740	0.08	6700	0.04	1.2	0.21	<0 1	<0.01	3.2
510	APR	0 07	19	<0.003	0.005	0.07	4 7	19	62	0.13	470	0 10	0.2	1 0	<0.1	<0.01	1 8
510	FER(ob)	0.88	1.5	<0.003	0.02	0.56	2.8	0.56	1.9	0.04	18	0.03	0.4	0.89	<0 1	0 01	0 88
510	ATR(s)	0 11	13	<0.003	0.006	0.14	1.1	21	35	0.09	460	0 01	0.2	3.3	<0.1	<0.01	0.50
510	ATR(p)	0.26	21	0.004	0.01	0.36	4.7	41	42	0.26	350	0.16	0 1	1.2	<0.1	<0.01	1.2
708	AMR	0.59	22	<0.003	<0.004	0.15	1 6	4.2	23	0.10	170	0.02	0.2	1.2	<0 1	<0.01	1 5
280	ER	<0 02	130	0.008	0 004	0.08	<0 01	140	420	0.05	3500	0.14	0 6	0.41	<0 1	<0.01	1 1
282	#1ACS	14	34	**0.84**	0 09	4.9	19	31	130	0.48	780	0.40	**88**	0.67	<0.1	<0.01	8.7
110	FER	0.79	210	0.009	0.008	0.56	13	360	710	0.46	7100	0 01	0.9	5 0	<0.1	<0.01	3.0
700	MR	0.26	140	<0.003	0.004	0.28	1.4	160	390	0 49	3500	0 08	<0.1	0 85	<0.1	0.02	18
700	AMR	0.65	36	**0.84**	0.05	1.1	5.1	51	52	0.58	990	0.18	0 1	68	<0.1	0.03	2.4
700	FMR	1.1	24	**0.85**	0.03	0.69	1.9	62	27	0.08	410	0.04	<0.1	27	<0.1	0.08	3.0
561	ER	0 65	27	0.007	<0.004	0 09	2 8	460	1700	0 33	11000	<0.01	3.0	0.40	0.8	<0.01	0.54
Onon	AMS	<0.02	51	<0.003	<0 004	0.03	0.97	53	160	0.15	1300	0.02	0 2	0.19	<0 1	<0.01	4.7
Onon	DS	0.16	24	**0.82**	<0.004	0 10	0 86	12	34	0.13	260	0.02	0.2	**0.88**	<0.1	<0.01	**9.0**
Onon	ER	0.11	33	**0.87**	0.02	0.19	1.7	110	120	0.03	3000	0.02	0.5	31	0.2	<0.01	1.3
Onon	ACS	0.44	310	**0.88**	0.03	0.40	3.4	390	980	0.22	10000	0.02	1.5	0.28	<0.1	<0.01	6.3
YRG62		0.06	28	**0.85**	0.01	0.10	37	29	84	2.6	750	0 05	0.2	0.44	<0 1	<0.01	**100**
YTL59		0.62	260	<0.003	<0.004	0.25	1 7	460	1200	0.13	12000	<0.01	1.6	0 11	<0.1	<0.01	1.0
YDG2		0.59	86	**0.82**	0.02	0.24	18	110	260	0 85	2700	<0.01	0 1	8.3	<0.1	<0.01	1 8

Figure 1 – Chromatogram of sample of 3-GP-11 naval distillate fuel.

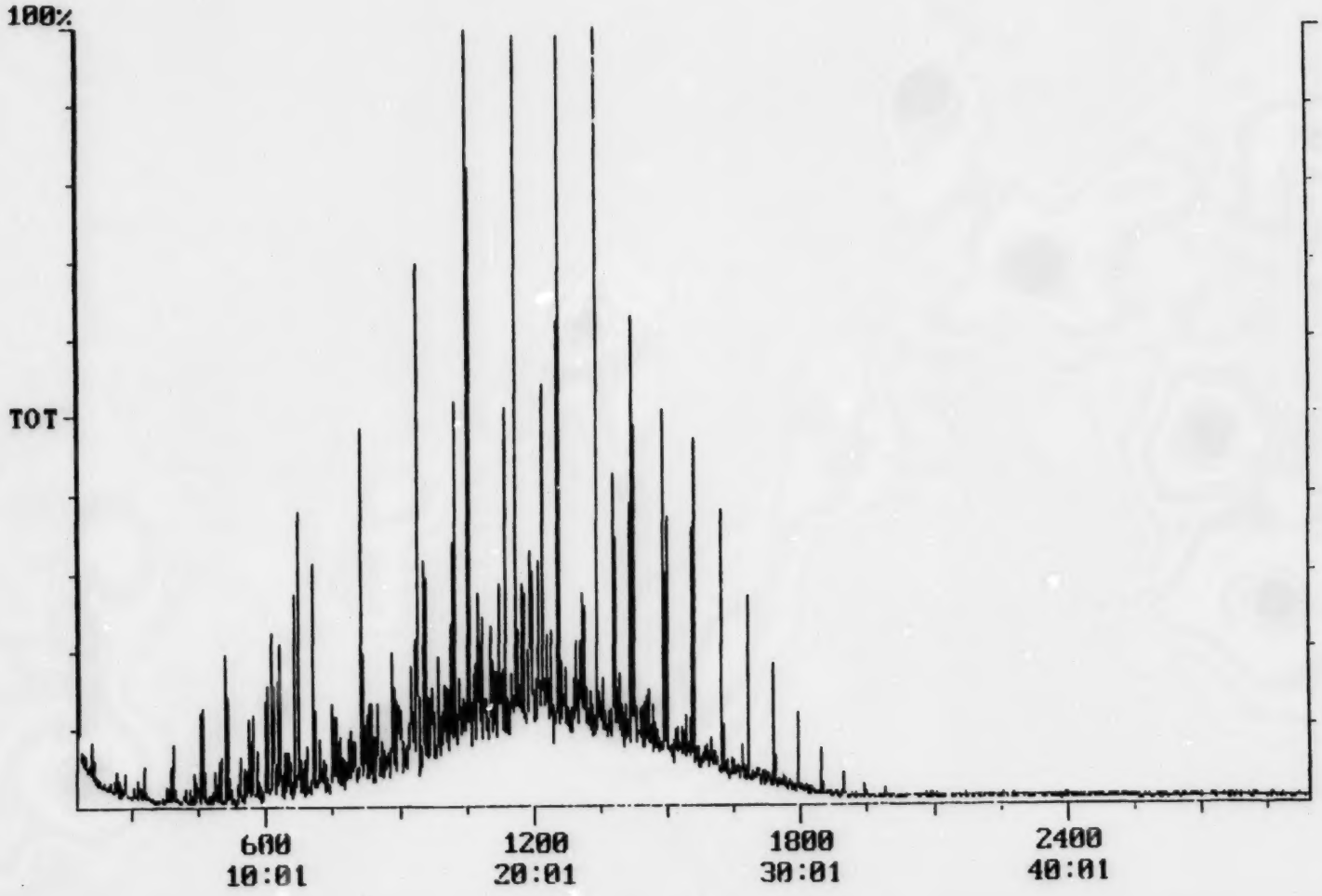


Figure 2 – Chromatogram of sample of NATO F44 aviation turbine fuel.

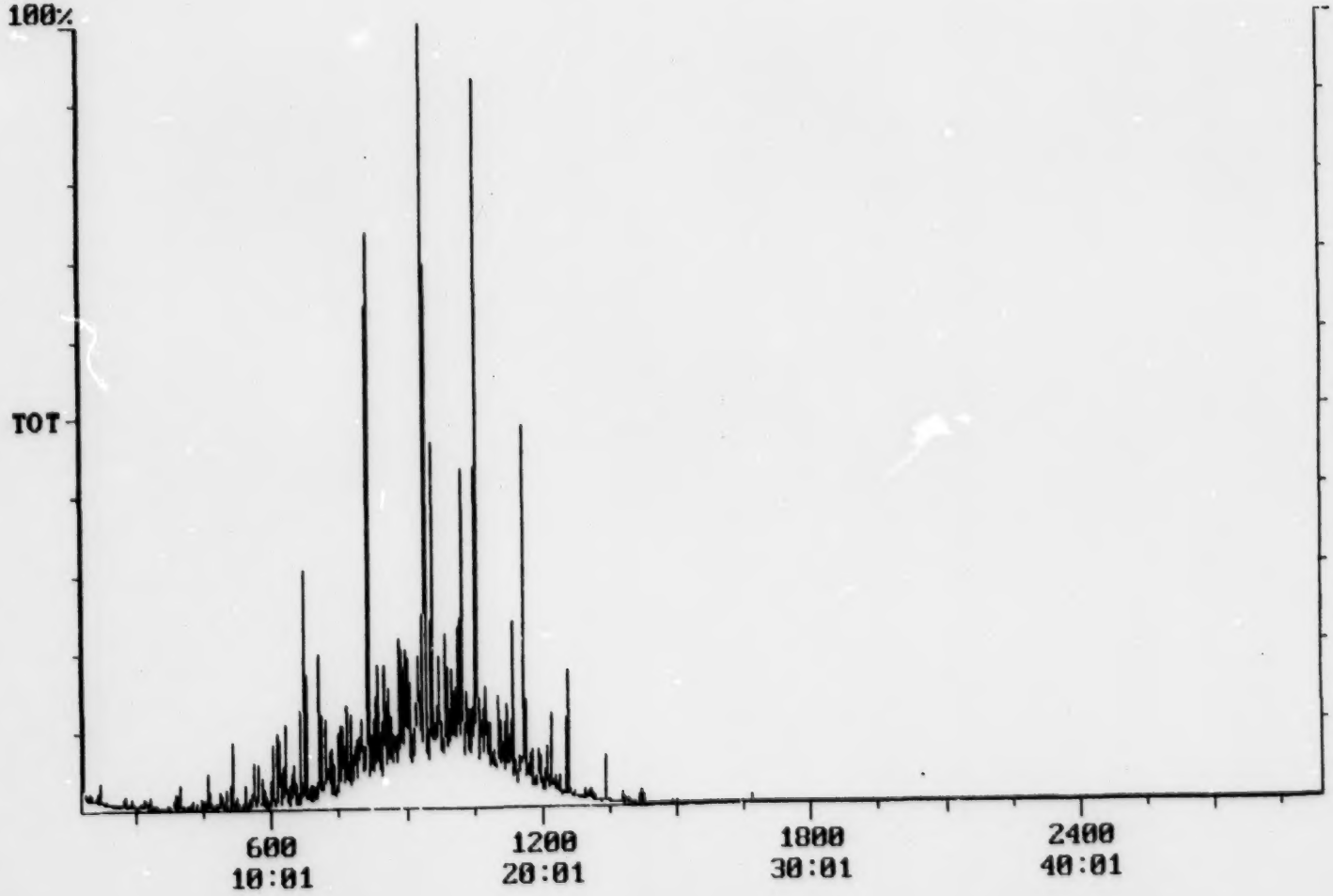


Figure 3 – Chromatogram of sample of MIL-L-9000 diesel lubricating oil.

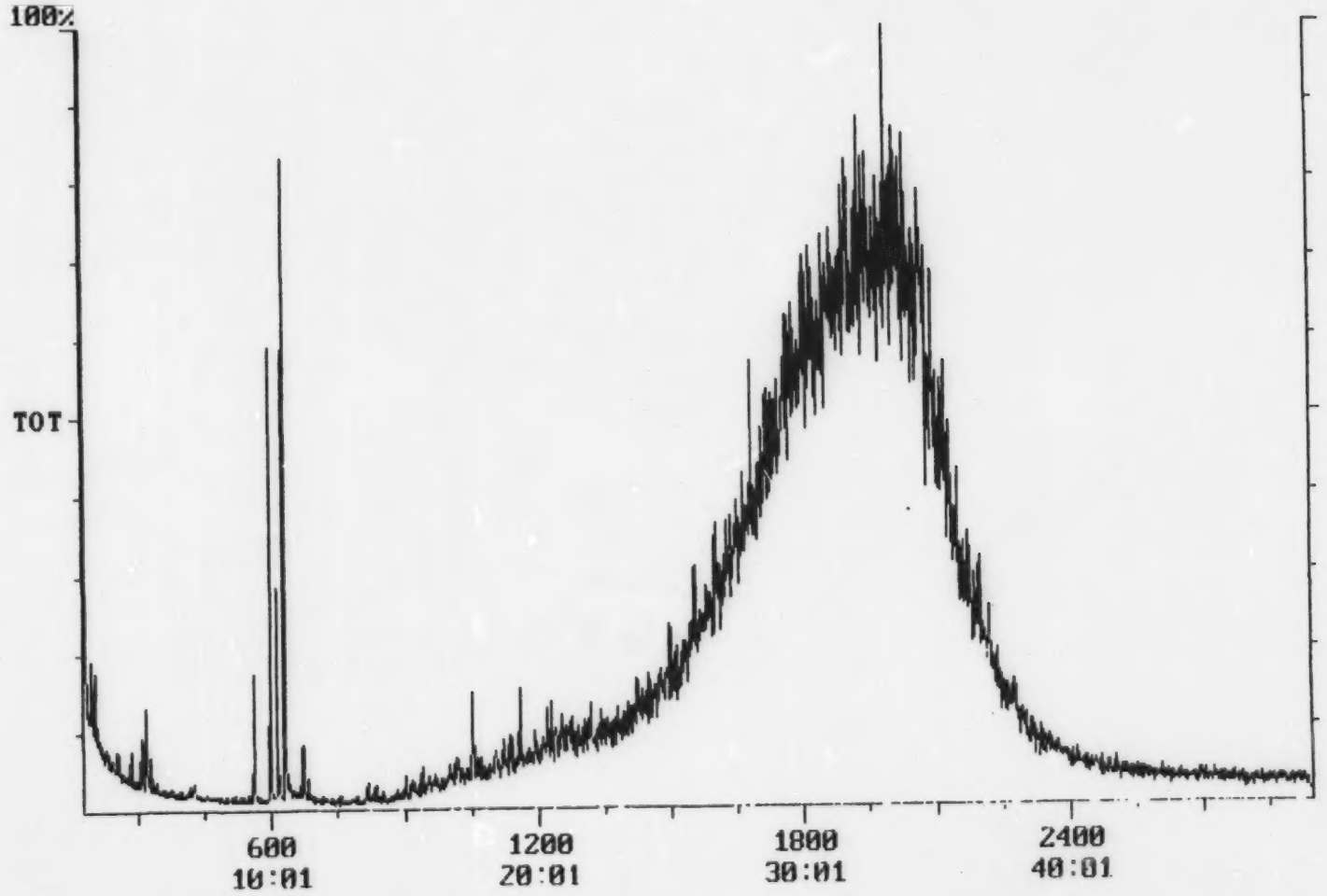


Figure 4 – Chromatogram of sample of MIL-L-23699 diesel lubricating oil.

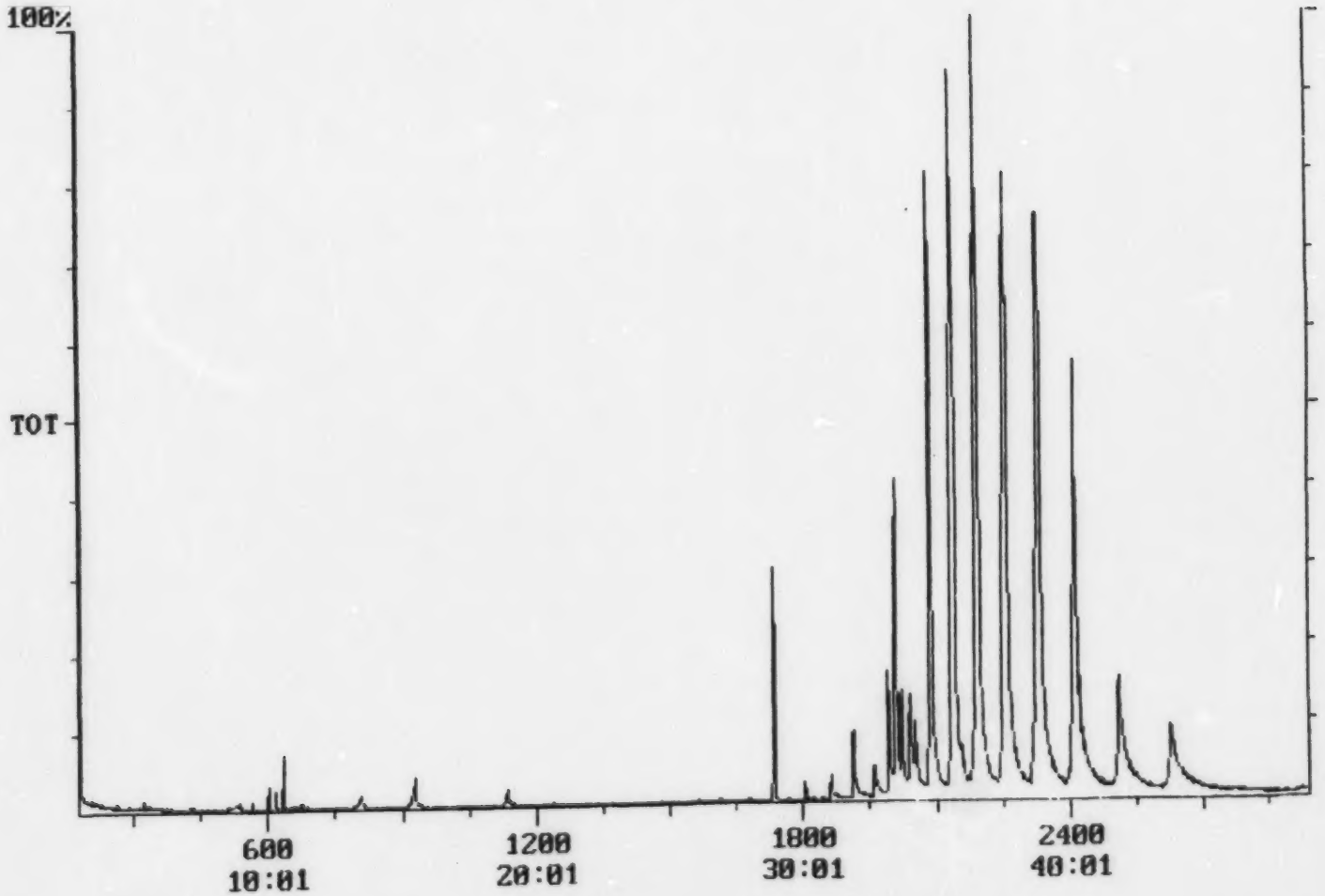


Figure 5 – Chromatogram of the organic layer of bilge sample 280ER.

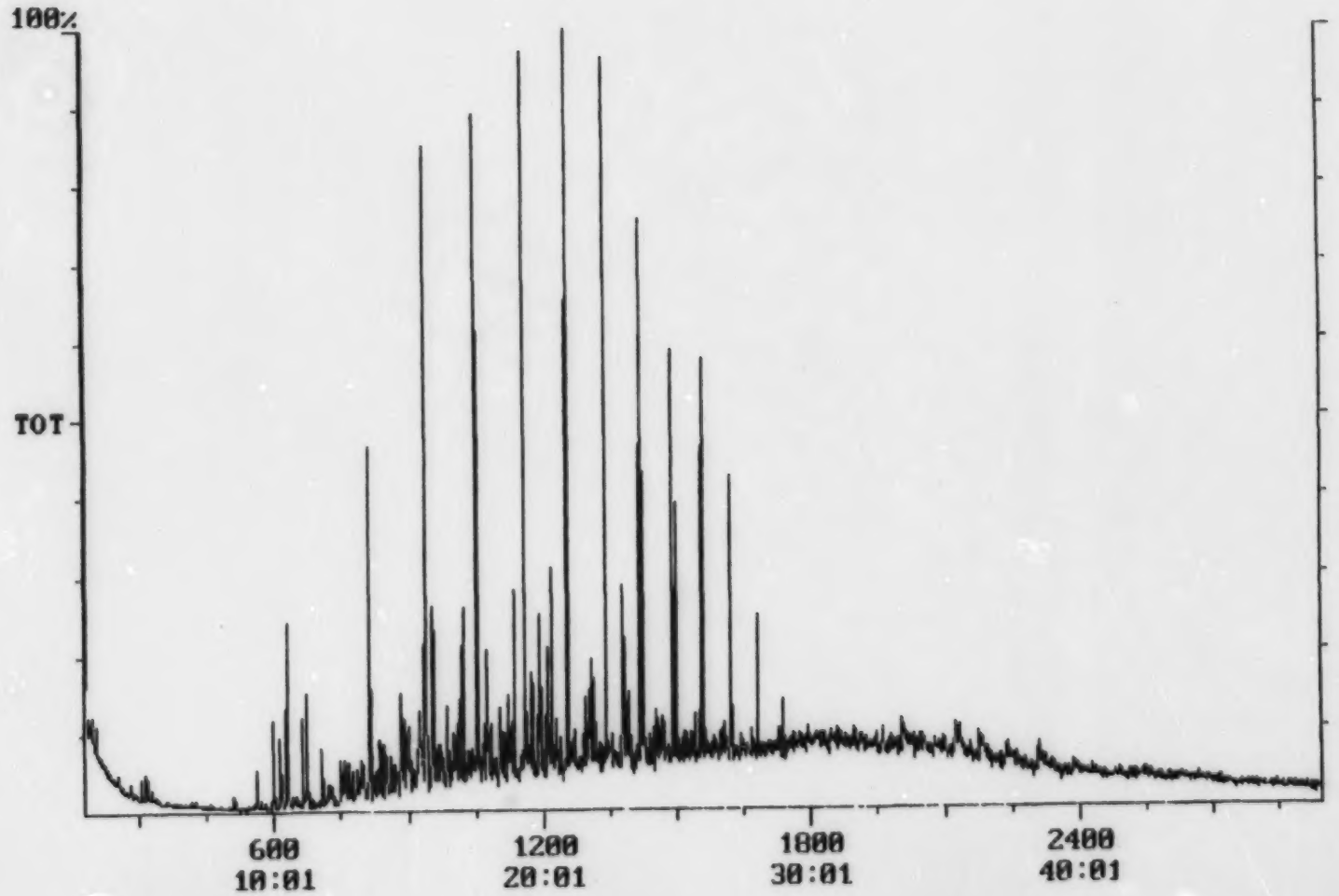


Figure 6 – Chromatogram of the organic layer of bilge sample 280AMR.

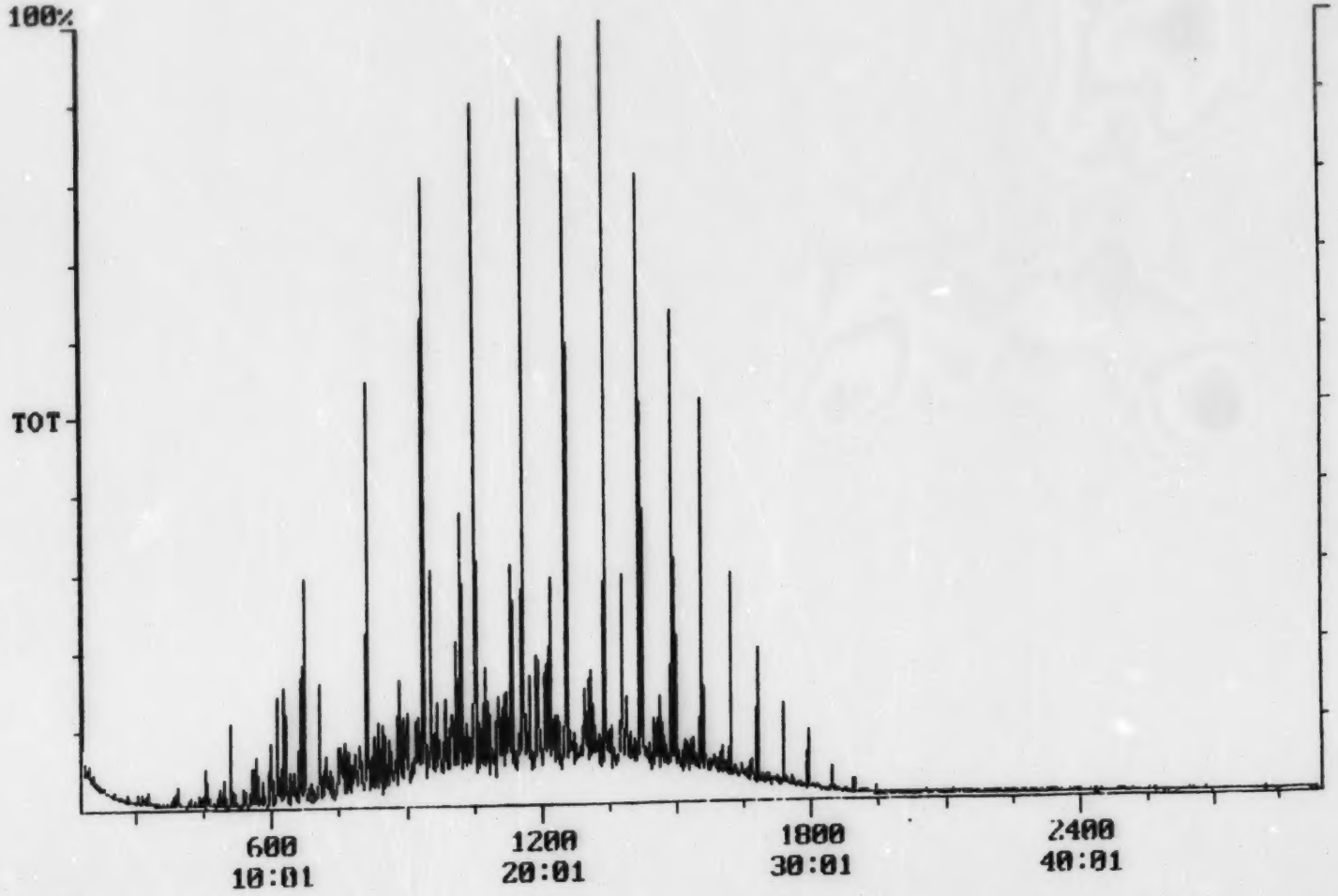


Figure 7 – Chromatogram of the organic layer of bilge sample 280Sull.

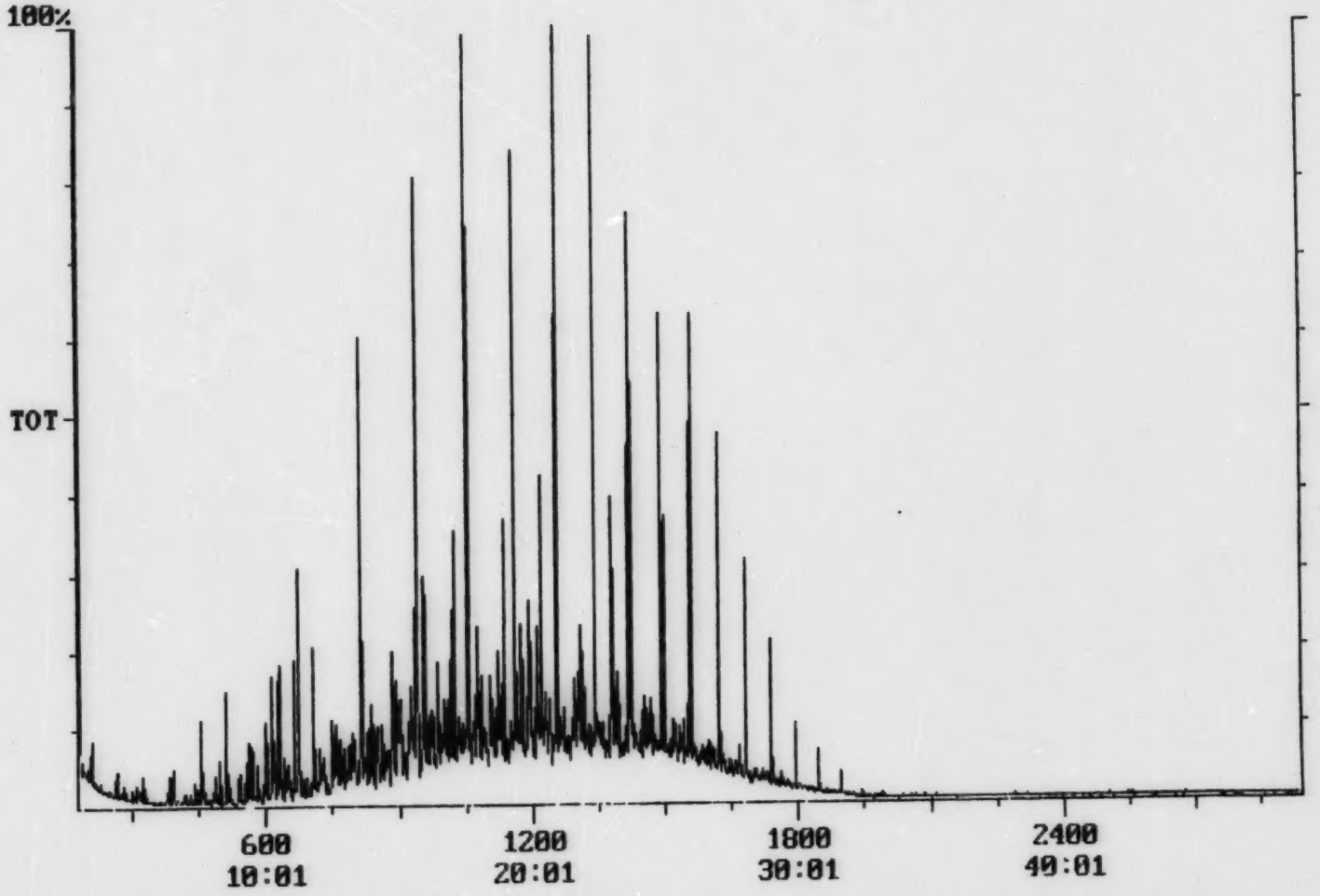


Figure 8 – Chromatogram of the organic layer of bilge sample 282ER.

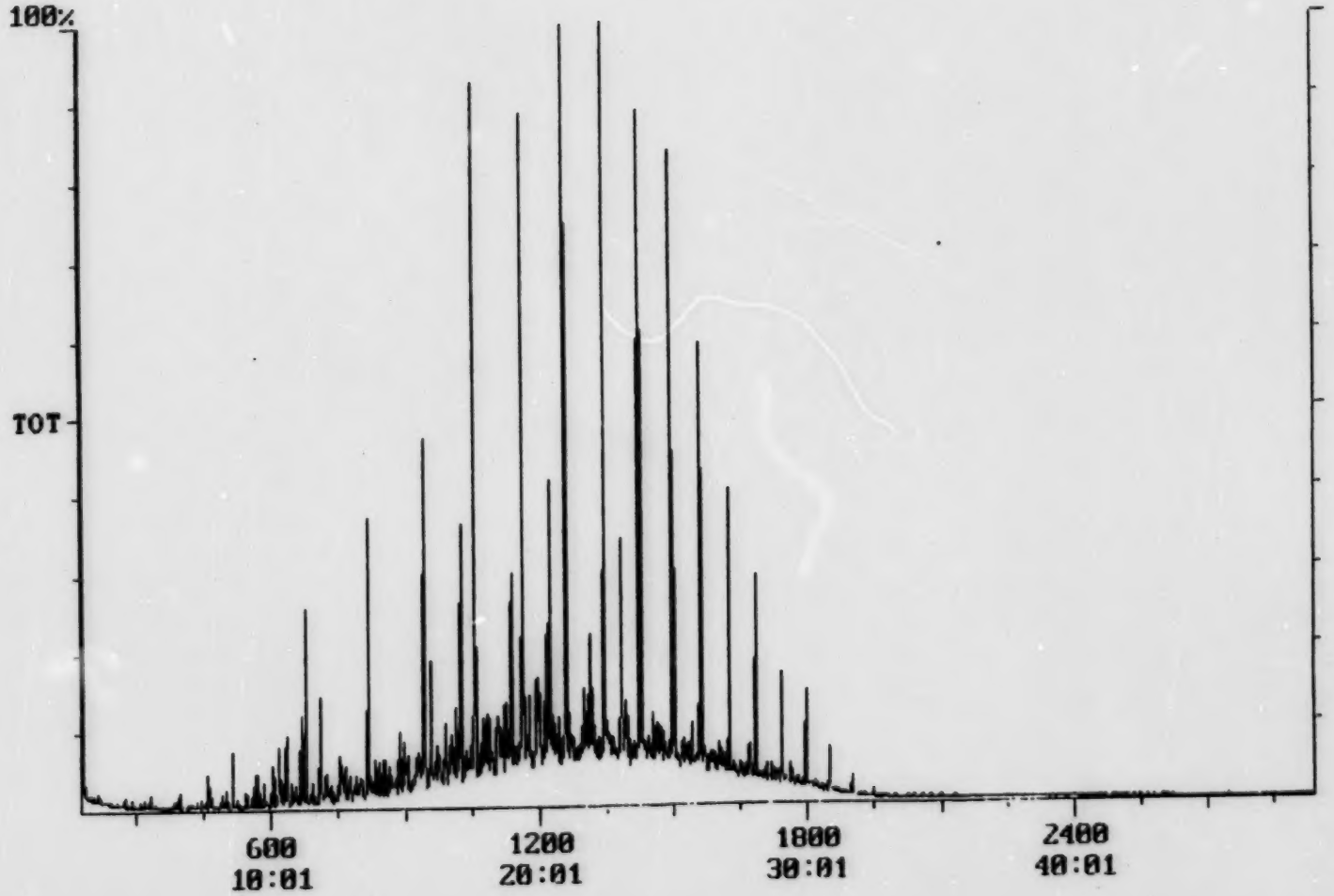


Figure 9 – Chromatogram of the organic layer of bilge sample 282#1ACS.

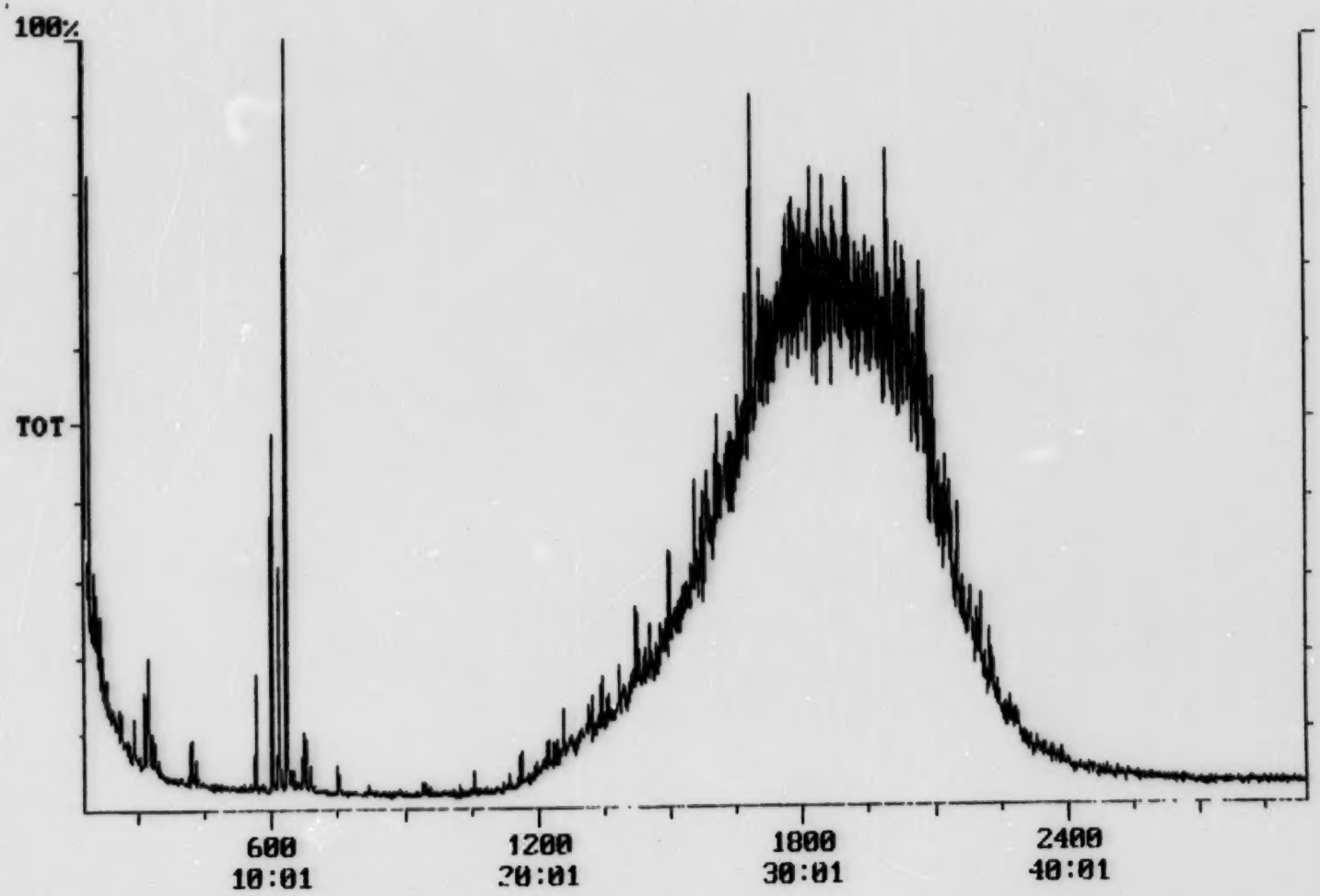


Figure 10 – Chromatogram of the organic layer of bilge sample 330OWC.

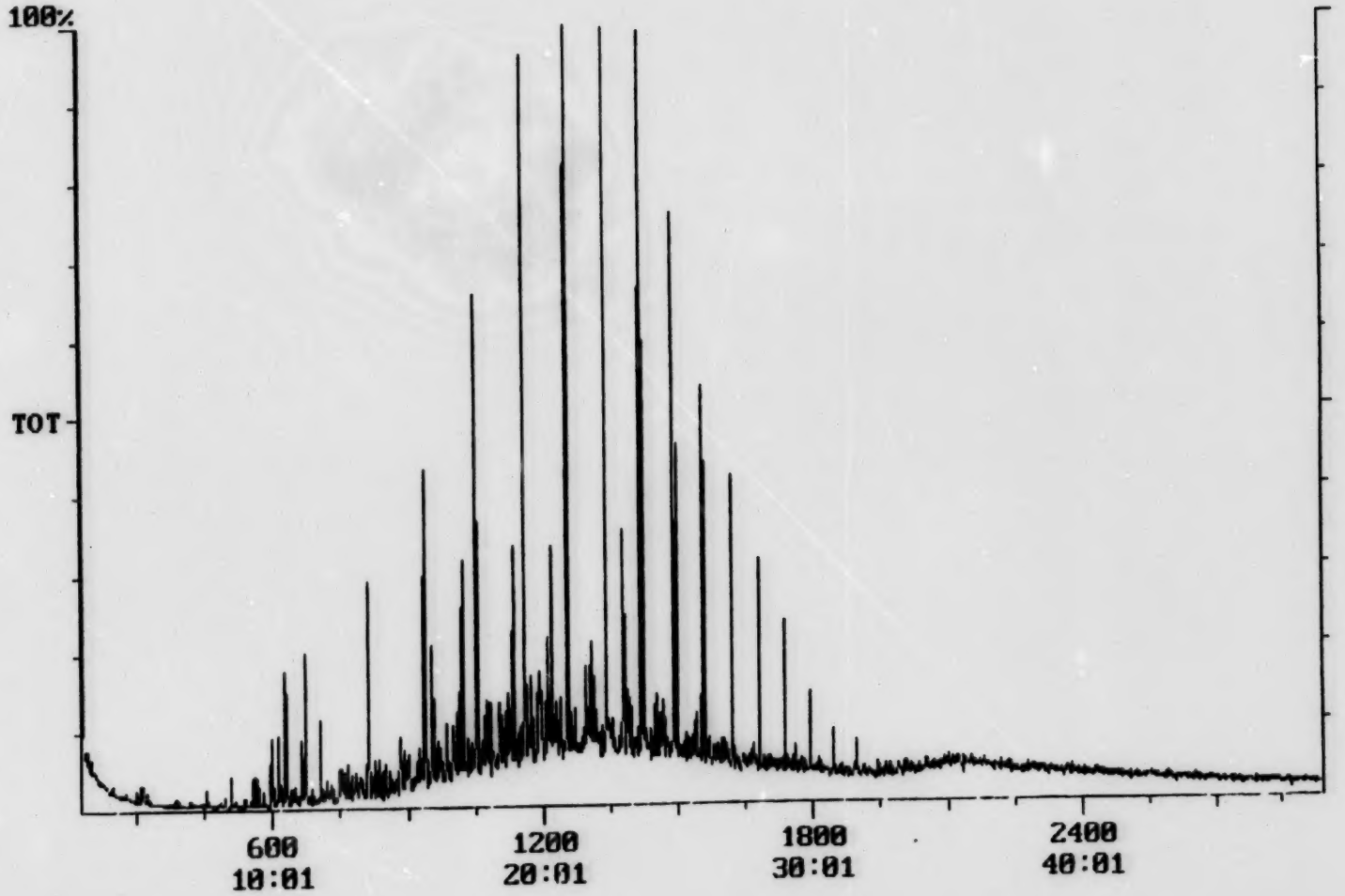


Figure 11 – Chromatogram of the organic layer of bilge sample 330AER.

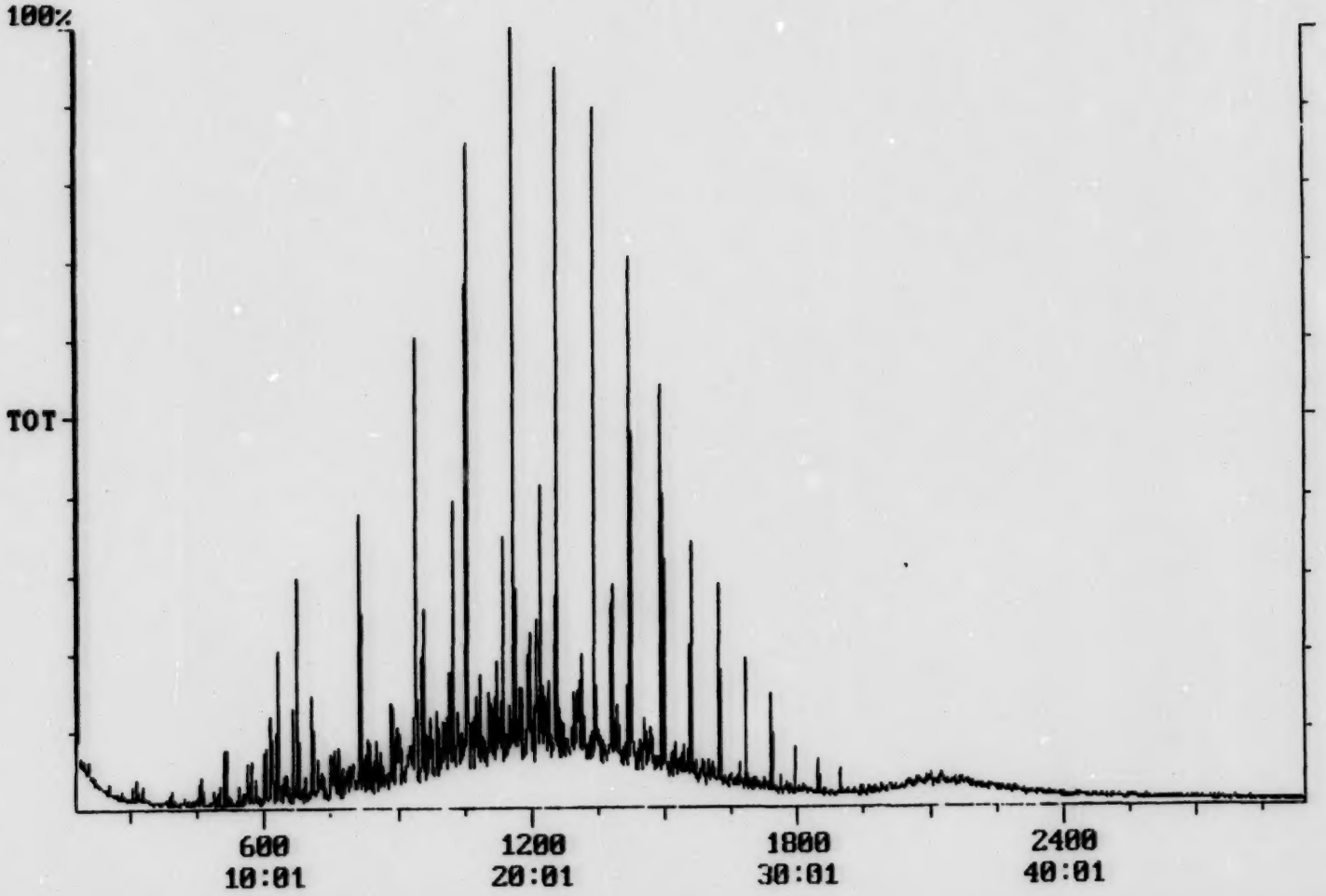


Figure 12 – Chromatogram of the organic layer of bilge sample 340FAMR.

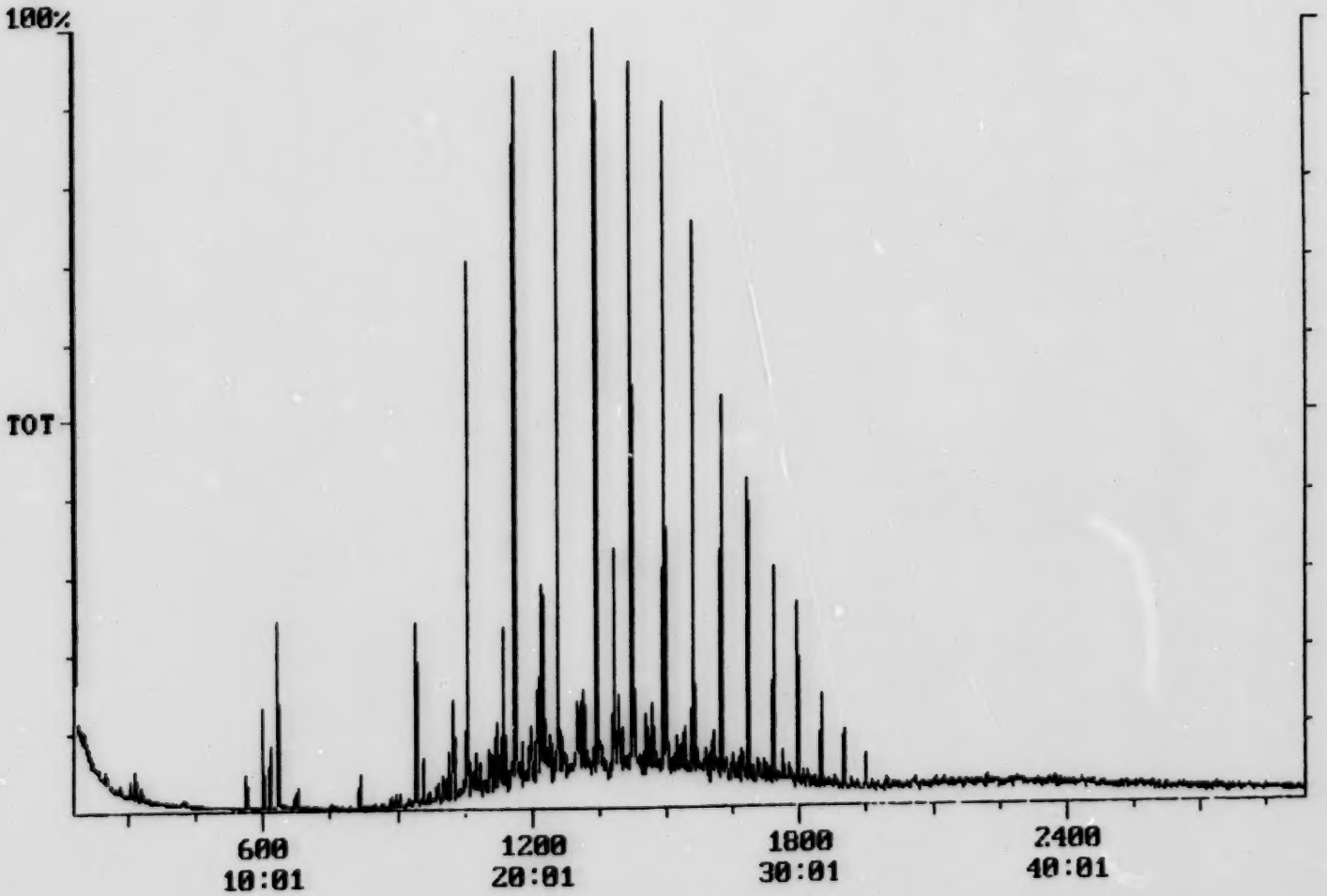


Figure 13 – Chromatogram of the organic layer of bilge sample 340AER.

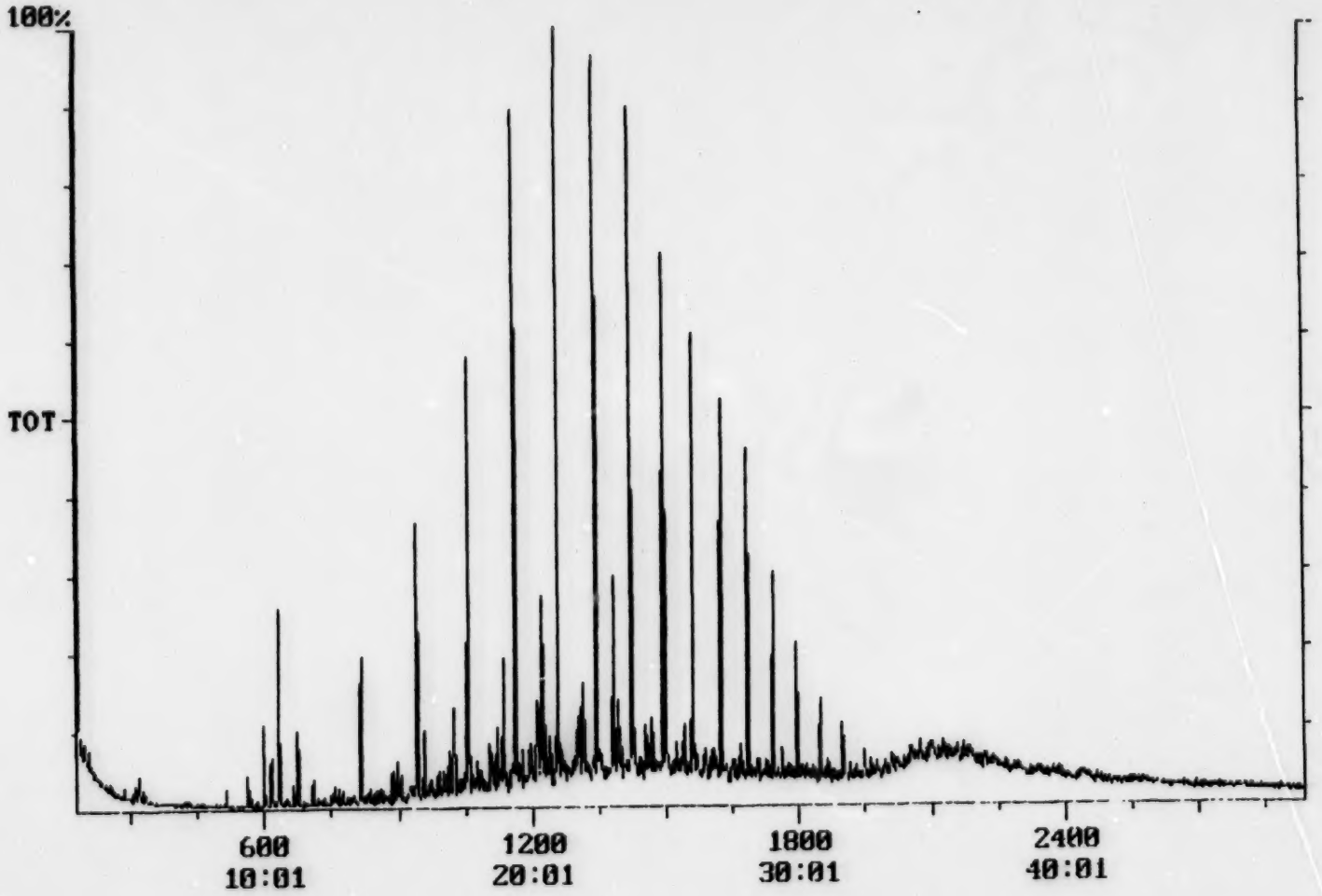


Figure 14 – Chromatogram of the organic layer of bilge sample 340AAMR.

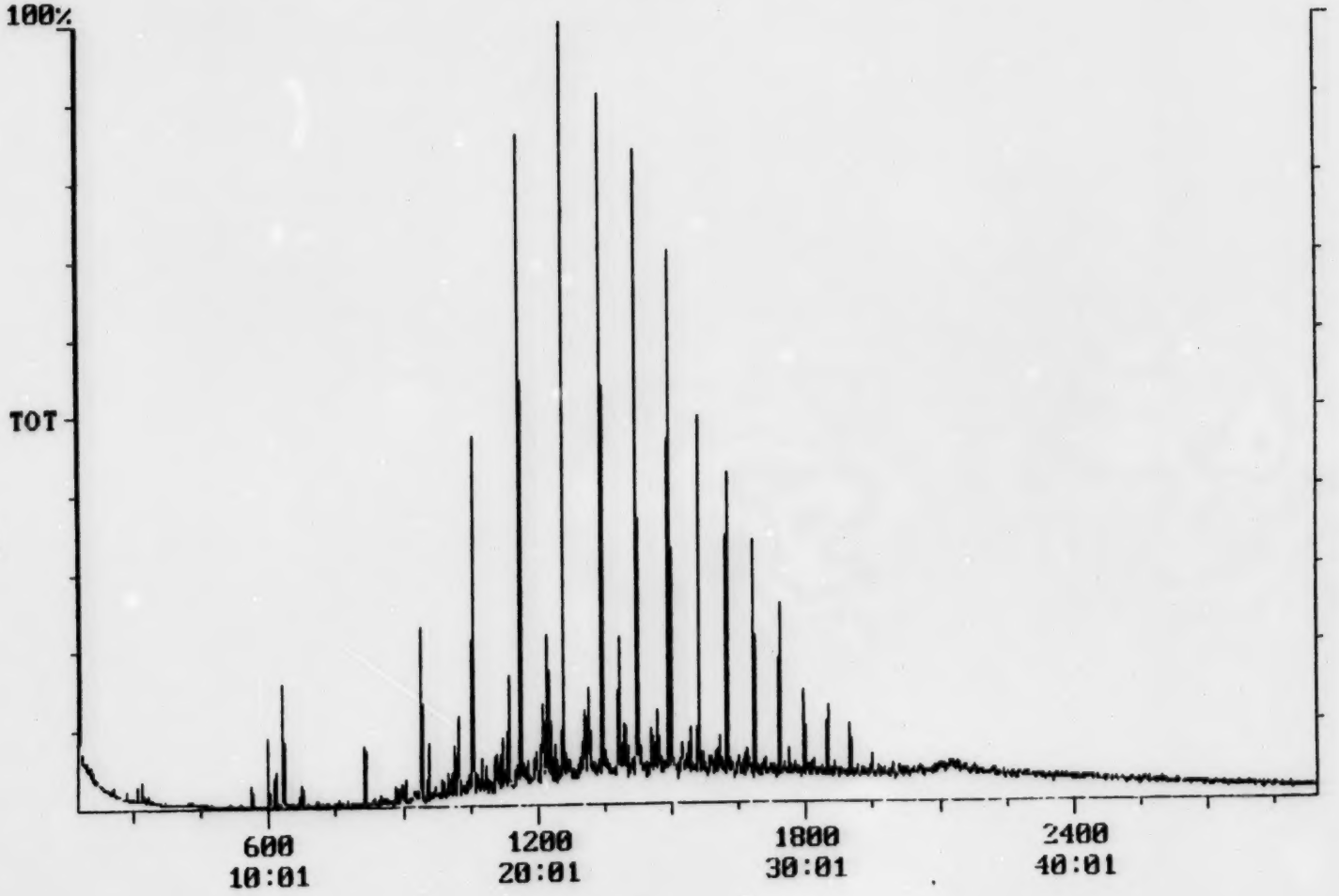


Figure 15 – Chromatogram of the organic layer of bilge sample 340FER.

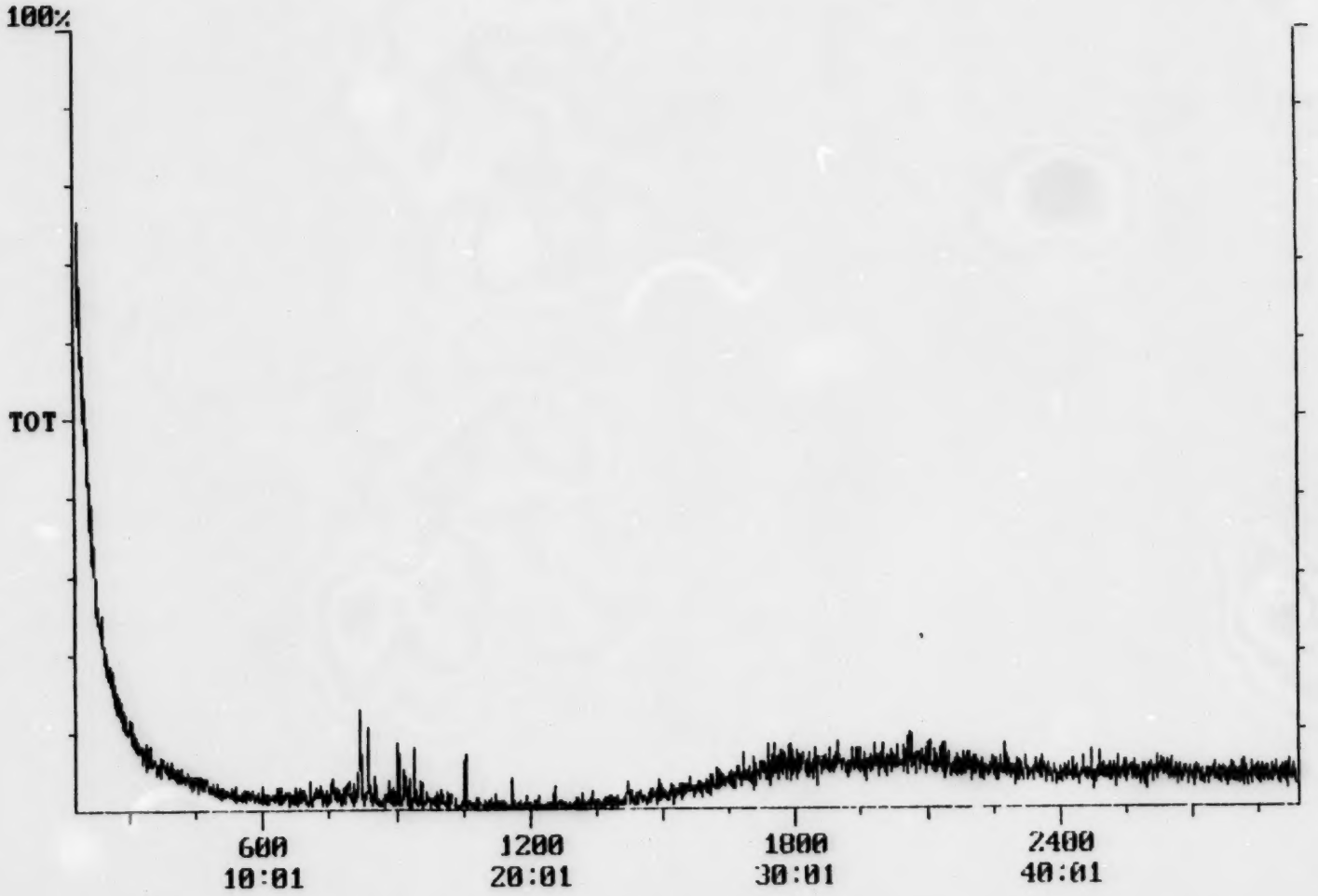


Figure 16 – Chromatogram of the organic layer of bilge sample 510APR.

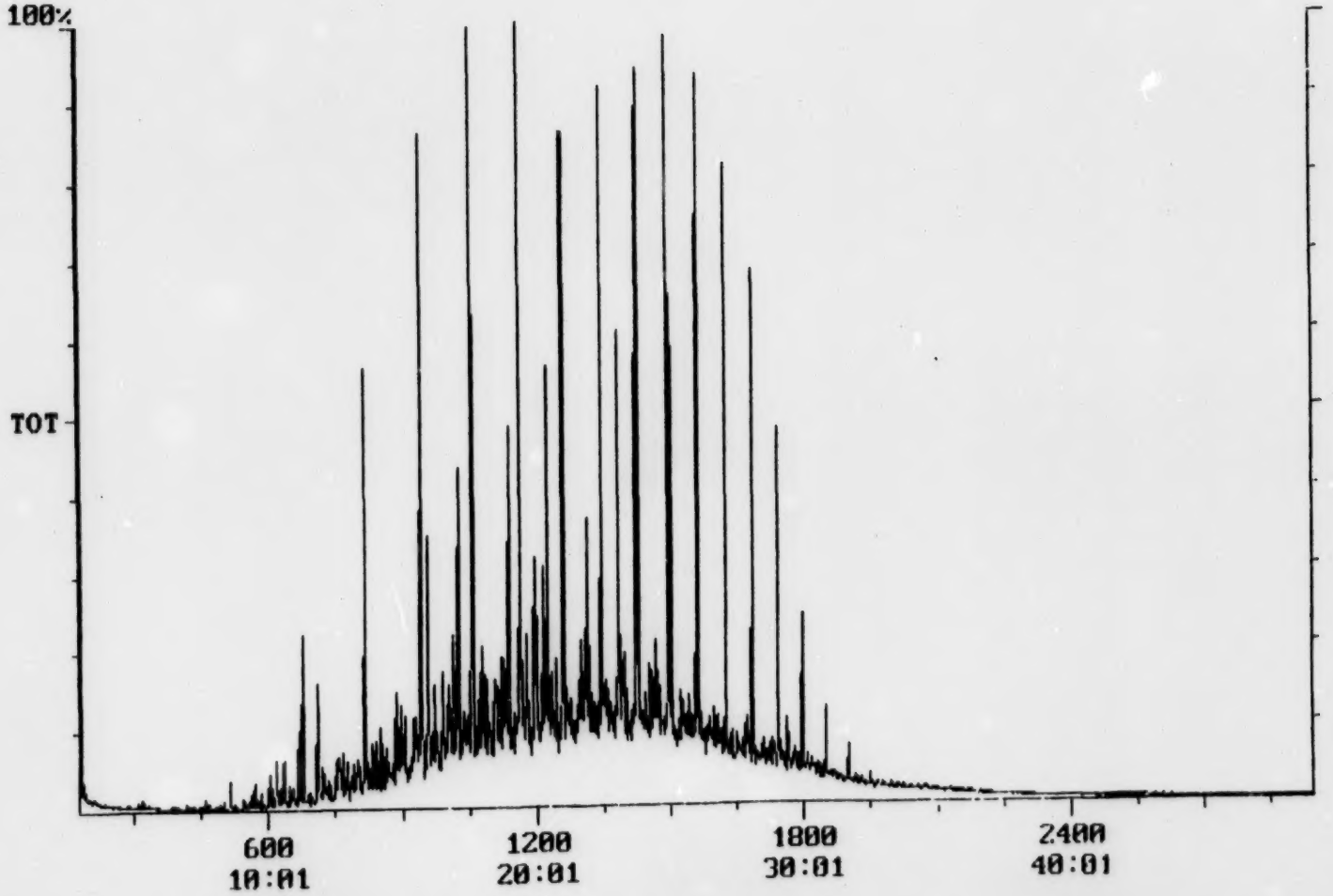


Figure 17 – Chromatogram of the organic layer of bilge sample 700MoR.

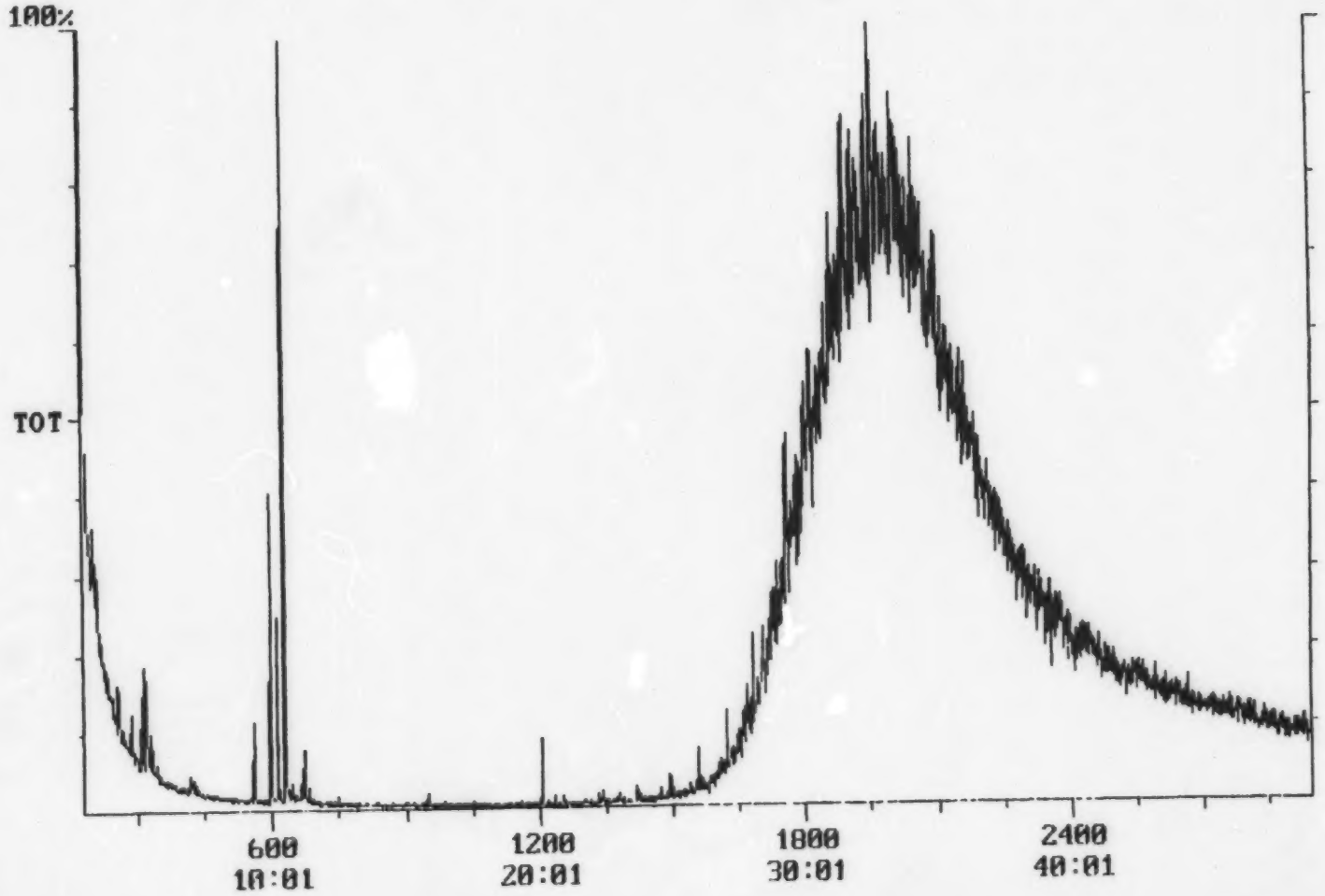


Figure 18 – Chromatogram of the organic layer of bilge sample 700FMR.

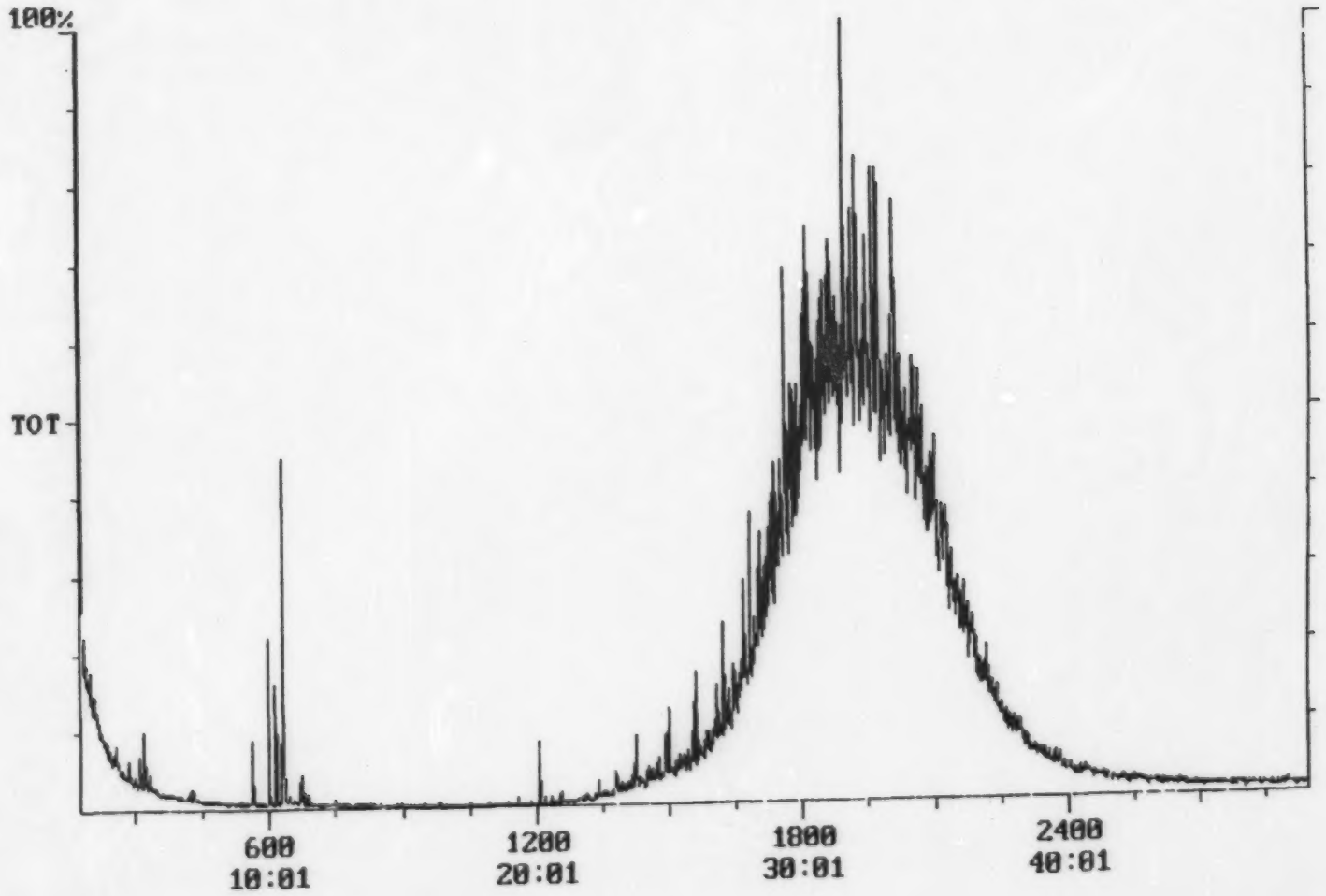


Figure 19 – Chromatogram of the organic layer of bilge sample 708FMR.

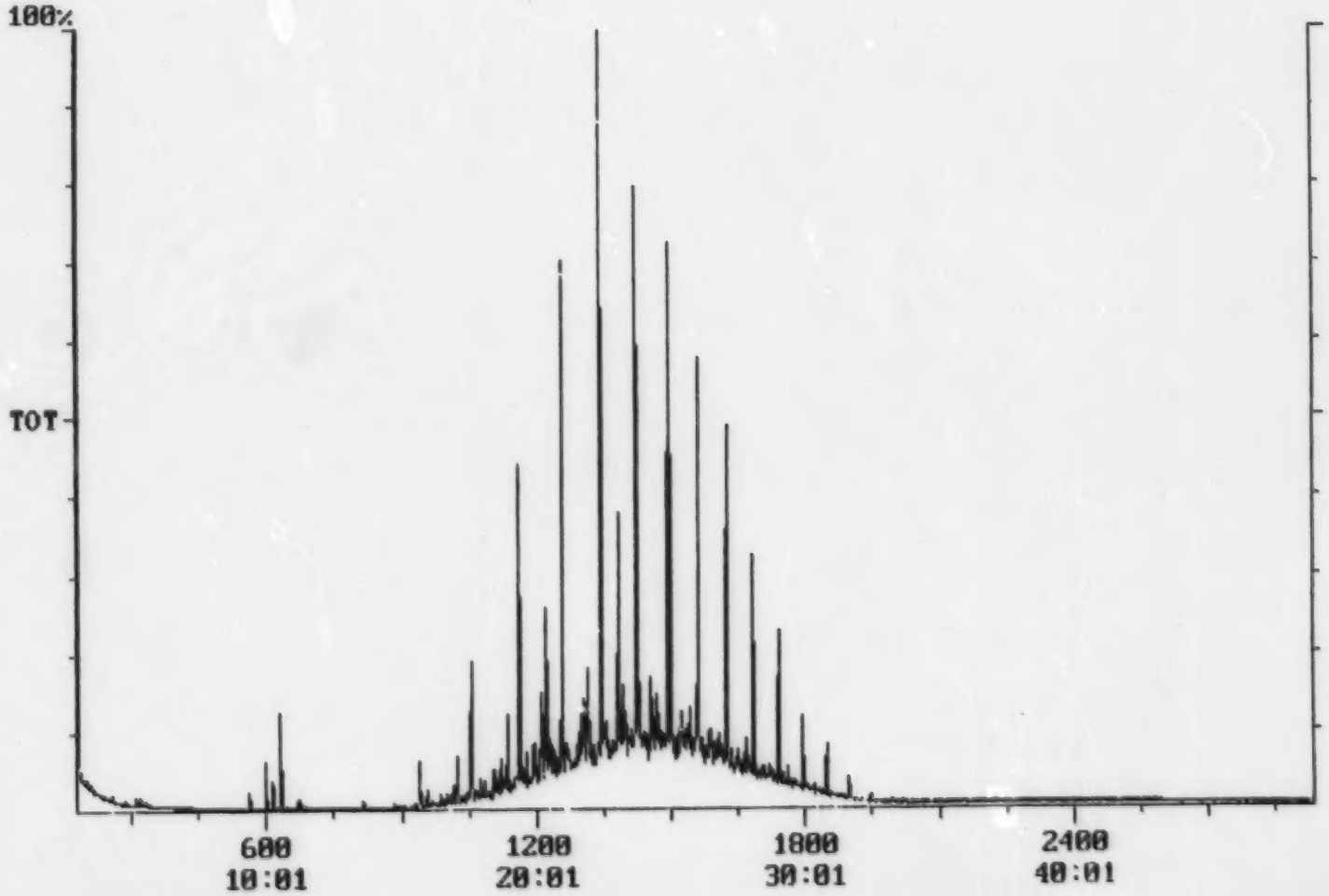


Figure 20 – Chromatogram of the organic layer of bilge sample 708AMR.

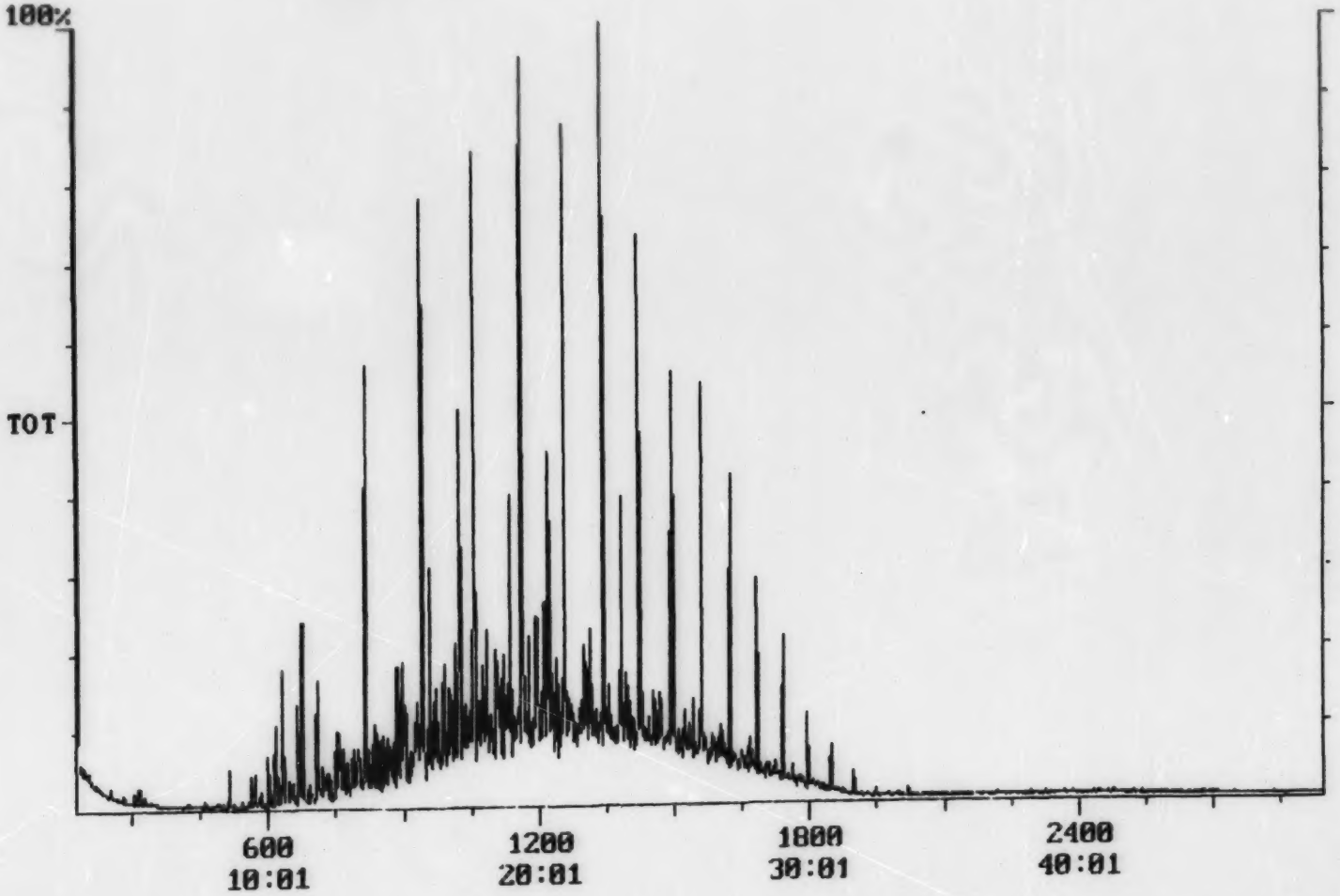


Figure 21 – Chromatogram of the organic layer of bilge sample YDG2.

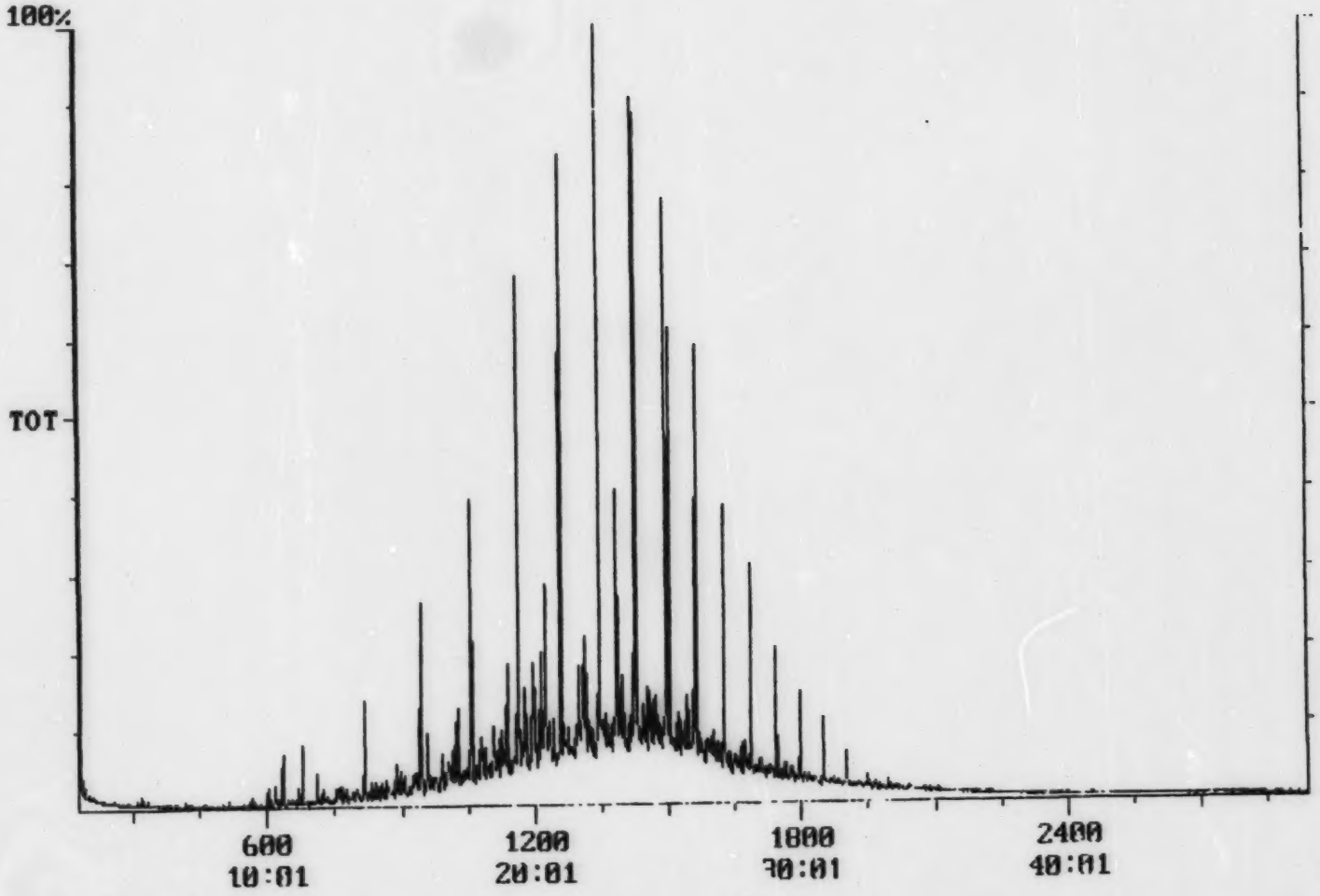


Figure 22 – Chromatogram of the organic layer of bilge sample YRG62.

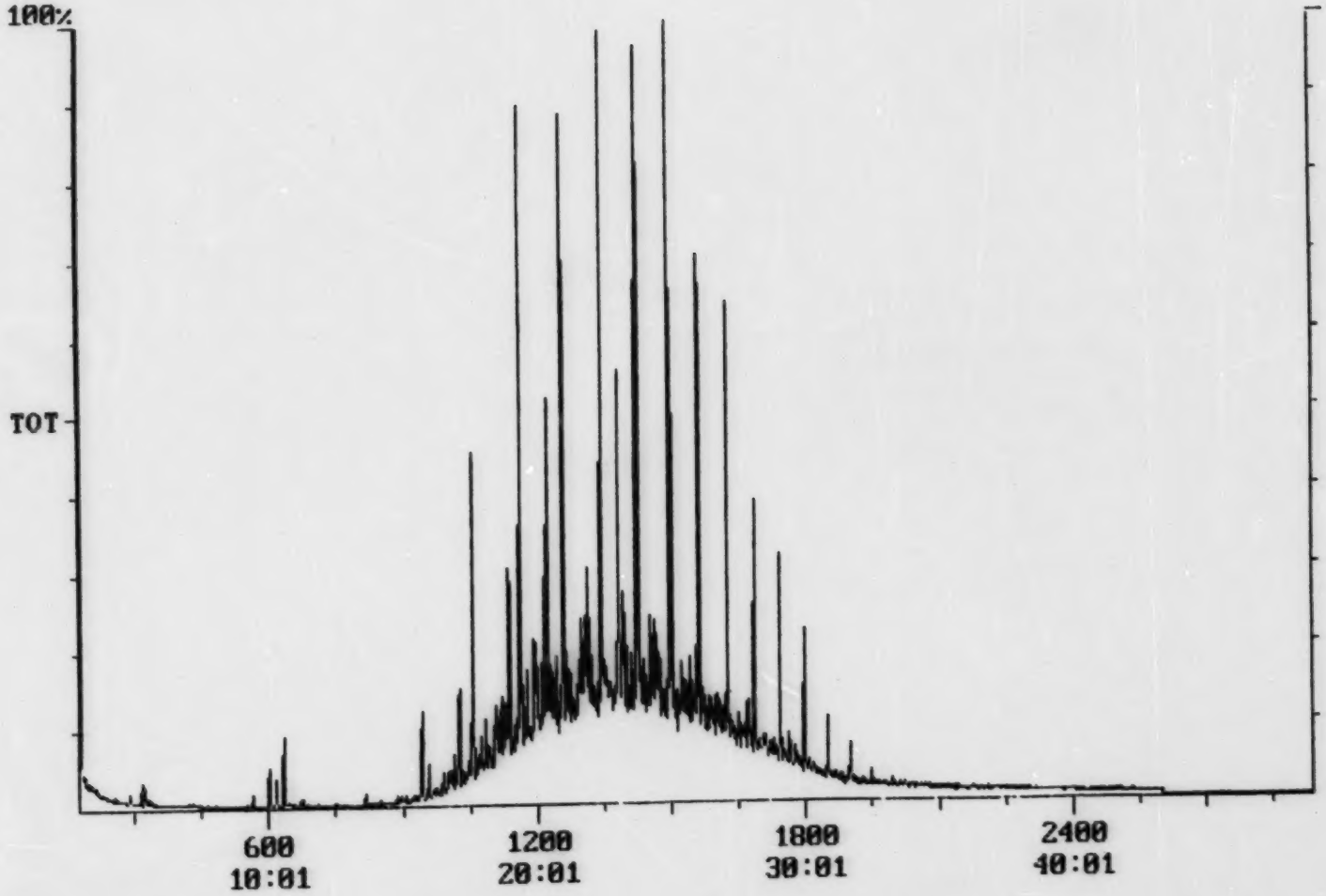


Figure 23 – Chromatogram of the organic layer of bilge sample YTL594.

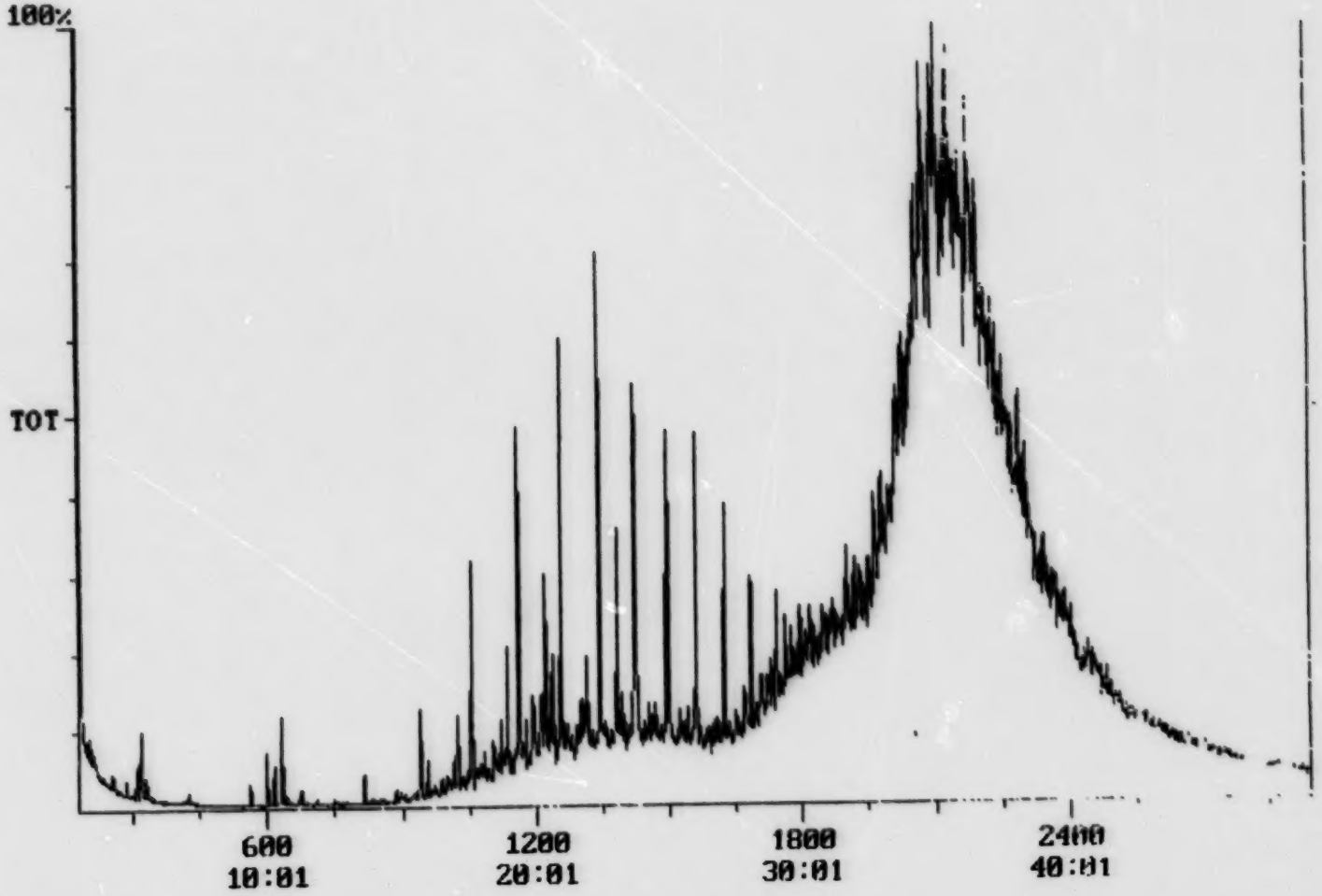
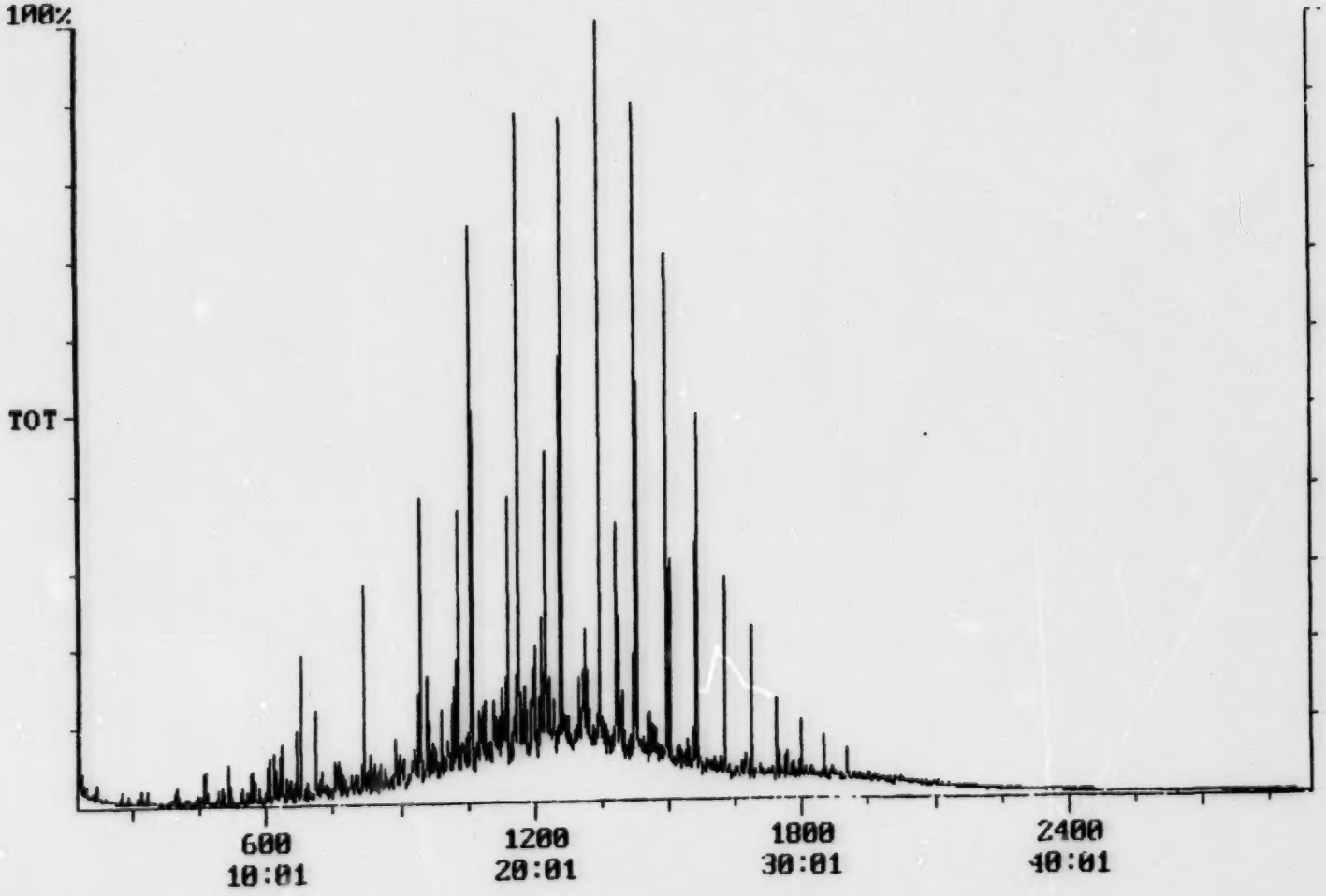


Figure 24 – Chromatogram of the organic layer of bilge sample 110FER.



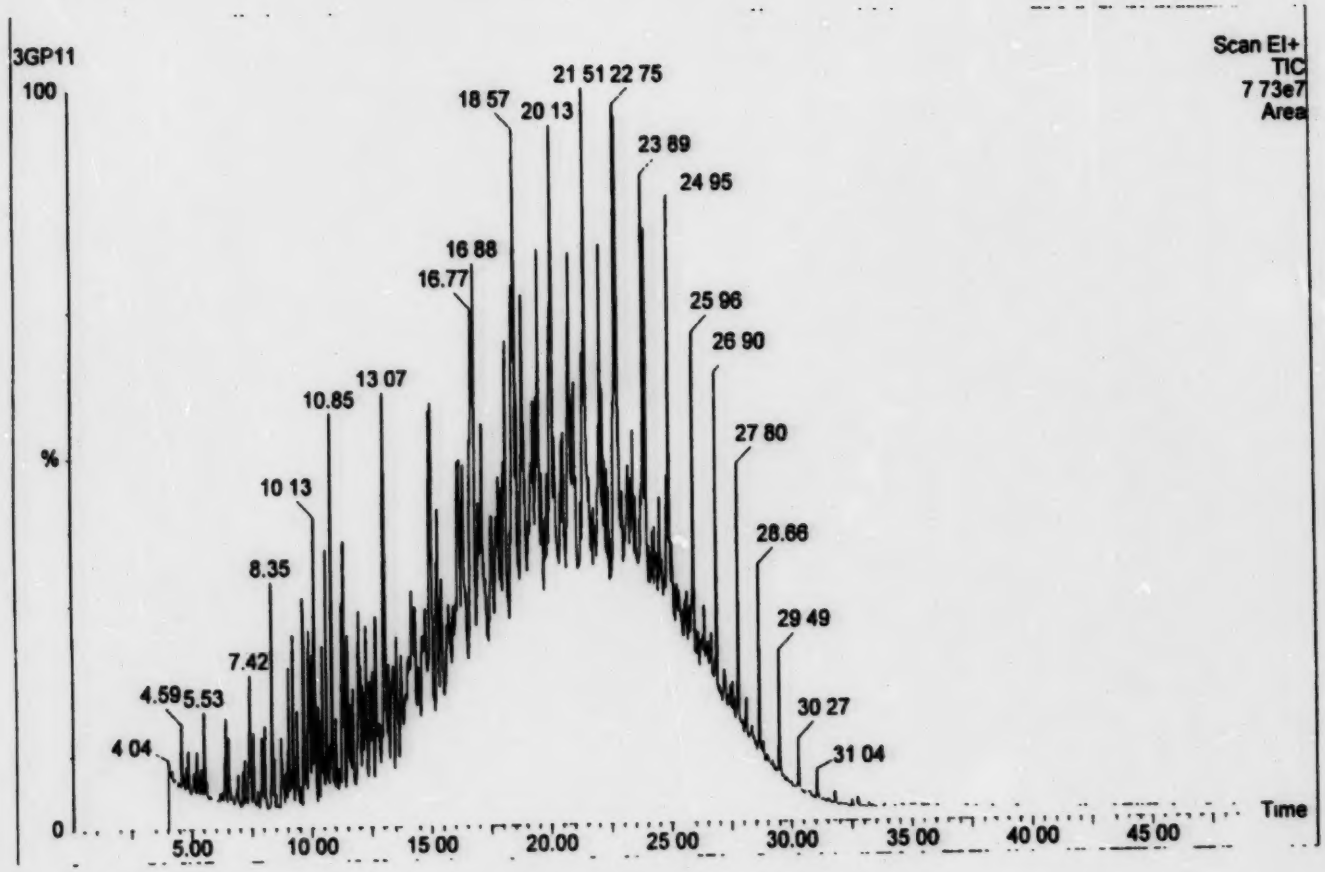


Figure 25 – Chromatogram of a sample of 3-GP-11 naval distillate fuel.

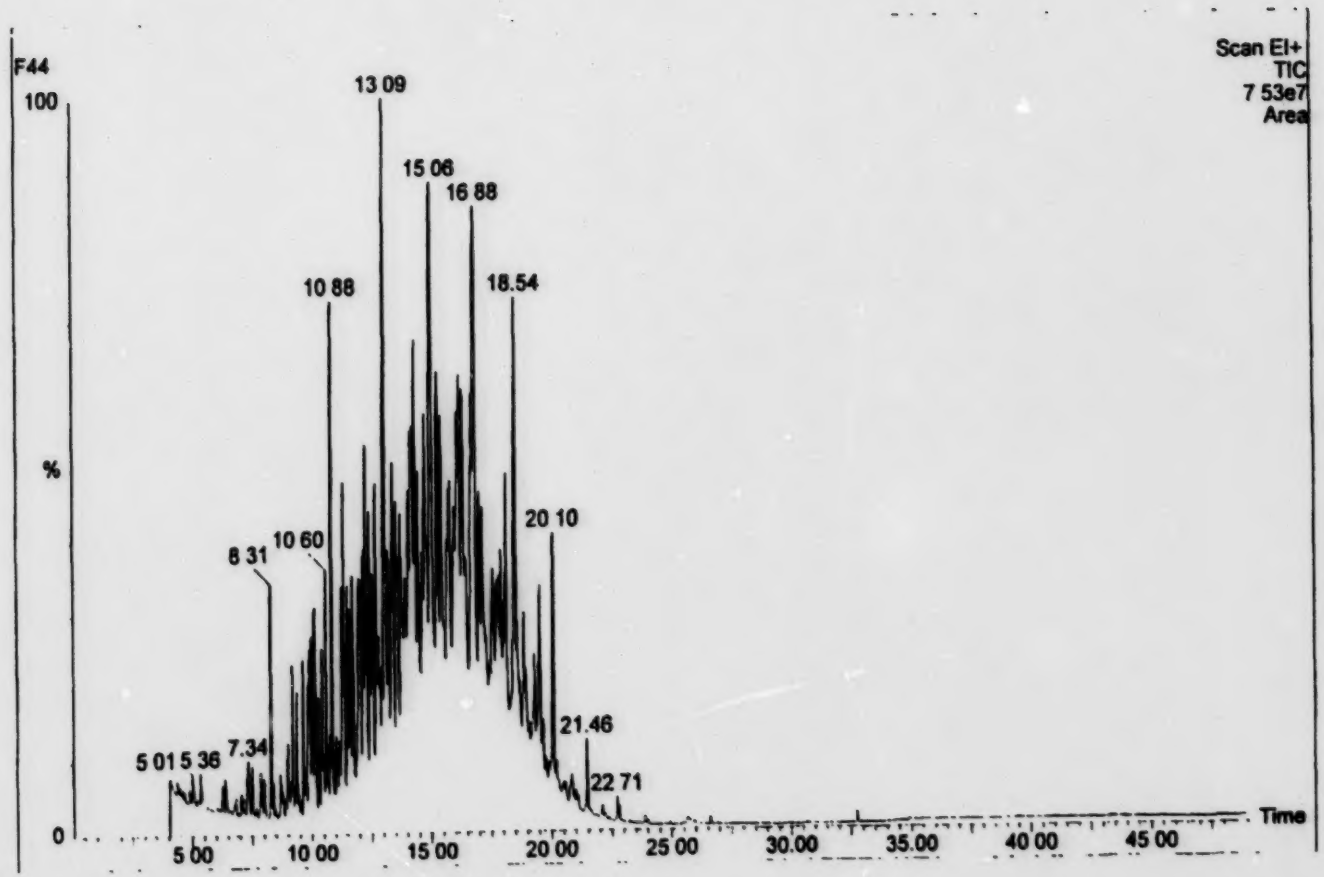


Figure 26 – Chromatogram of a sample of NATO F44 aviation turbine fuel.

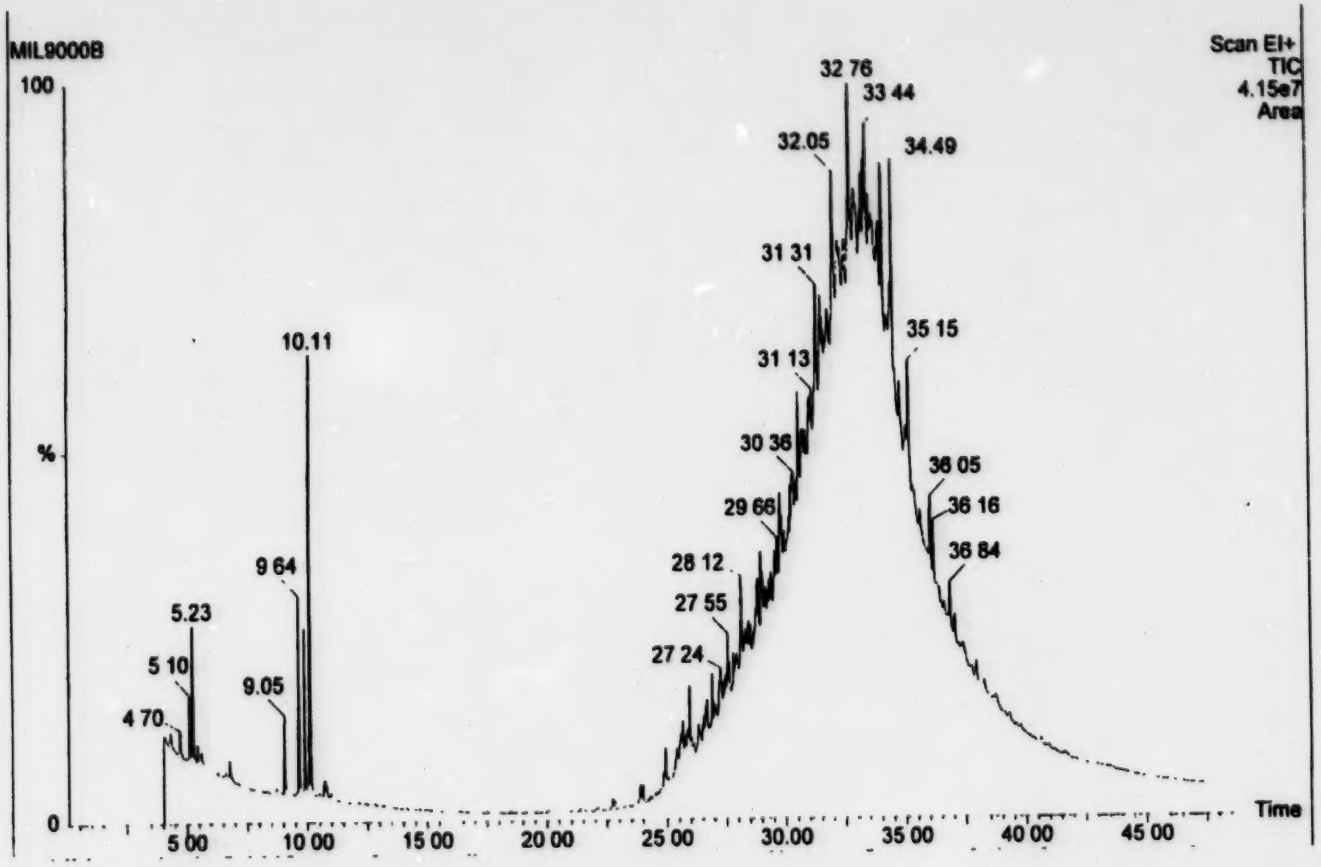


Figure 27 – Chromatogram of a sample of MIL-L-9000 diesel lubricating oil.

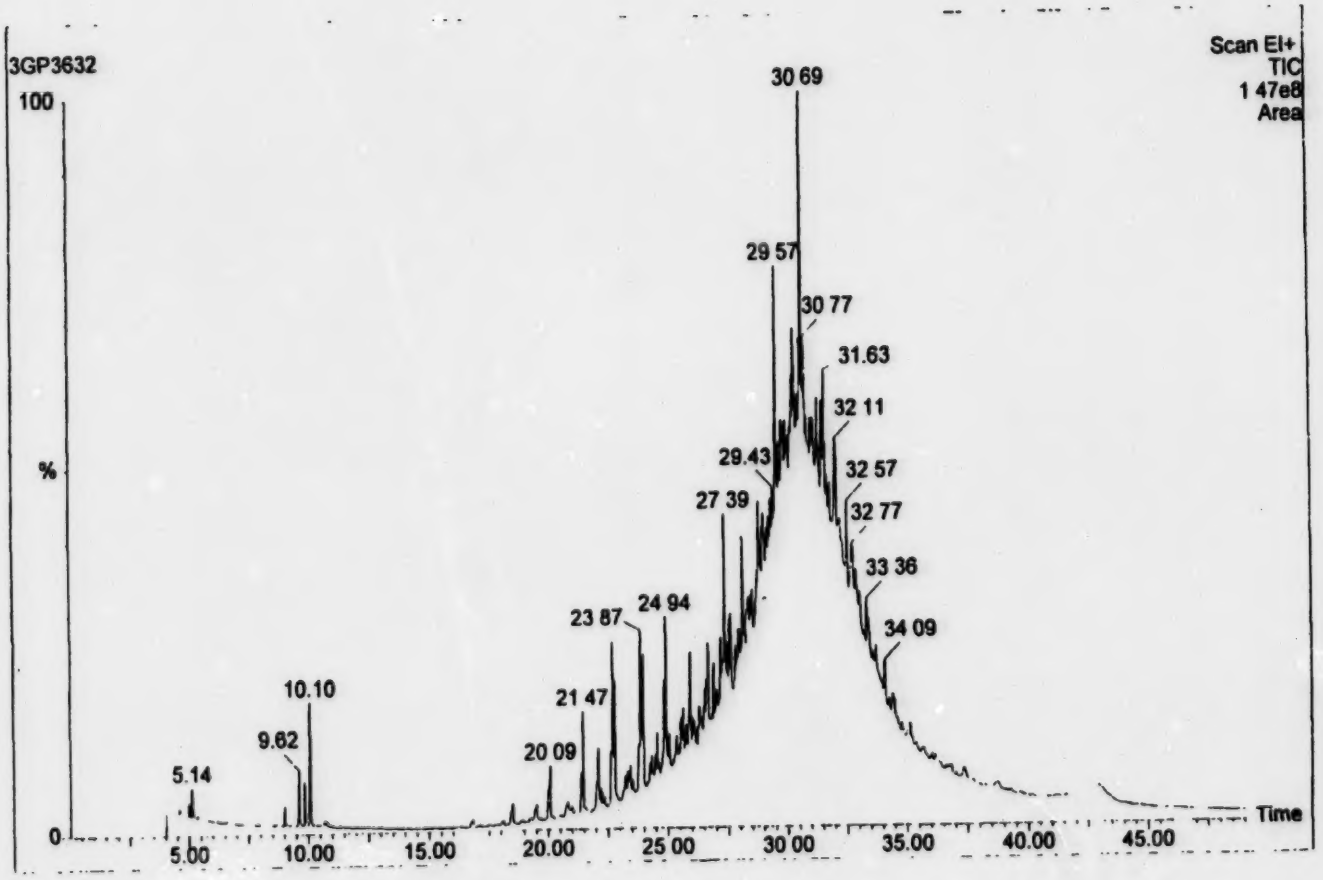


Figure 28 – Chromatogram of a sample of 3-GP-36 grade 32 hydraulic fluid.

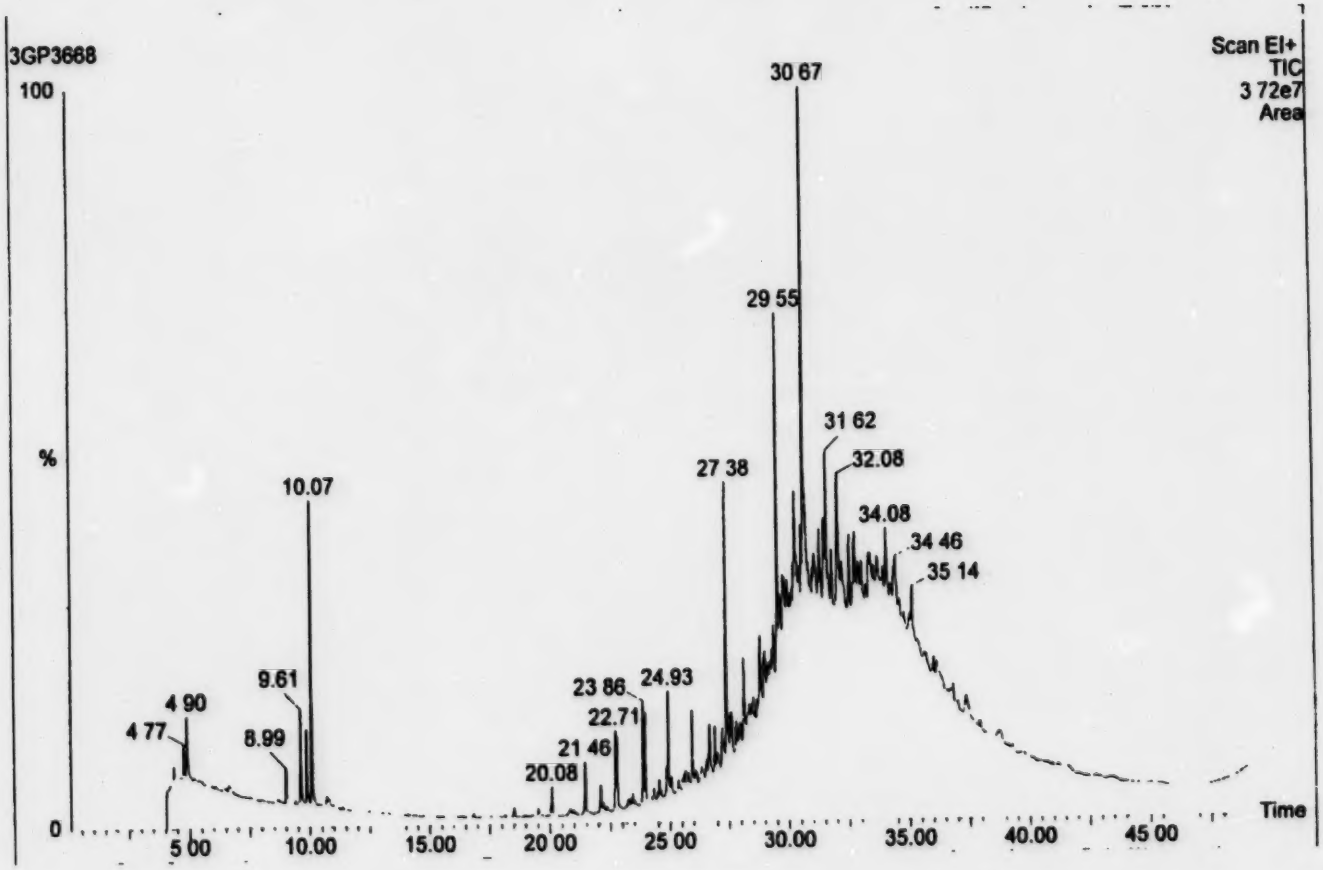


Figure 29 – Chromatogram of a sample of 3-GP-36 grade 68 hydraulic fluid.

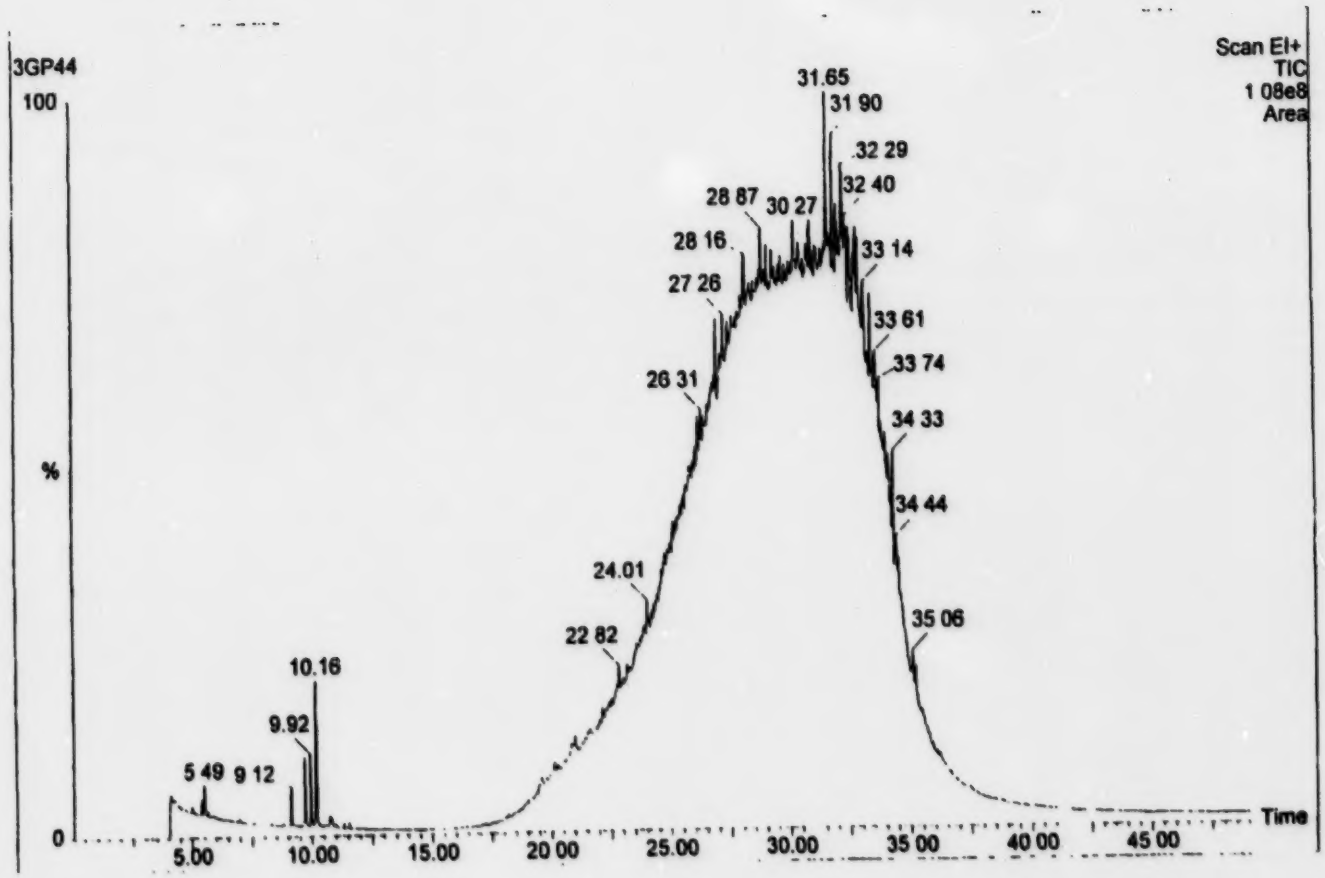


Figure 30 – Chromatogram of a sample of 3-GP-44 oil.

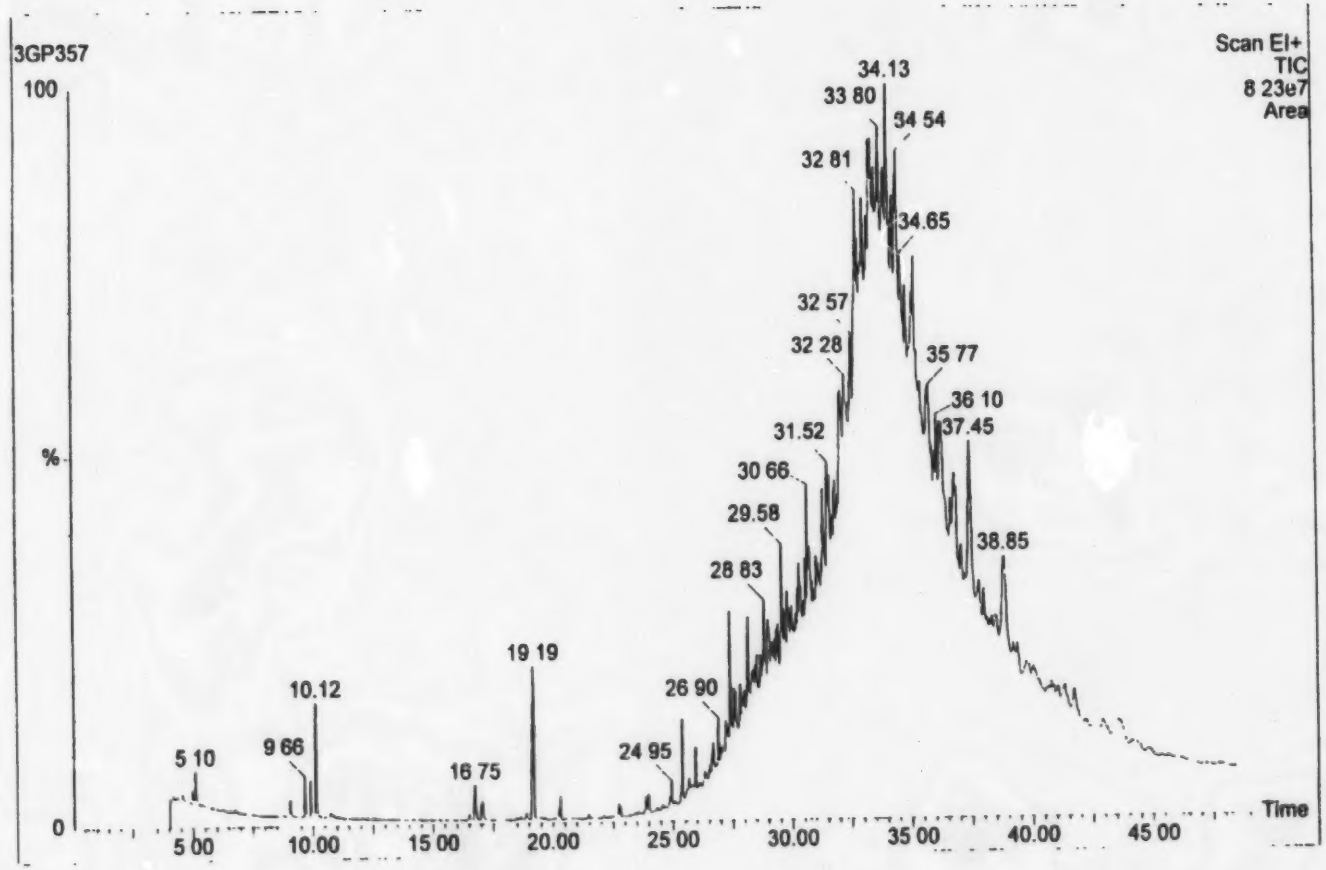


Figure 31 – Chromatogram of a sample of 3-GP-357 lubricating oil.

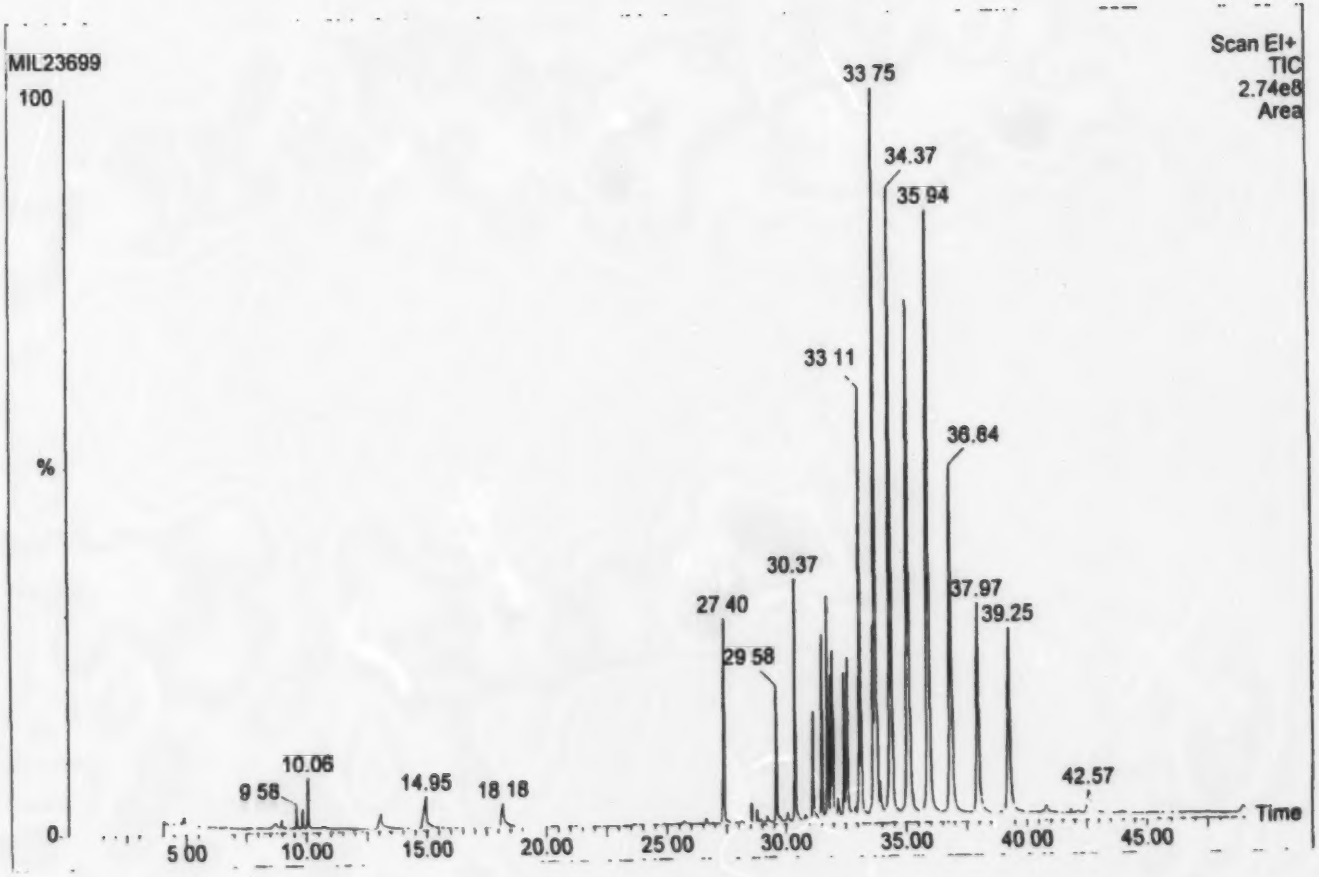


Figure 32 – Chromatogram of a sample of MIL-L-23699 lubricating oil.

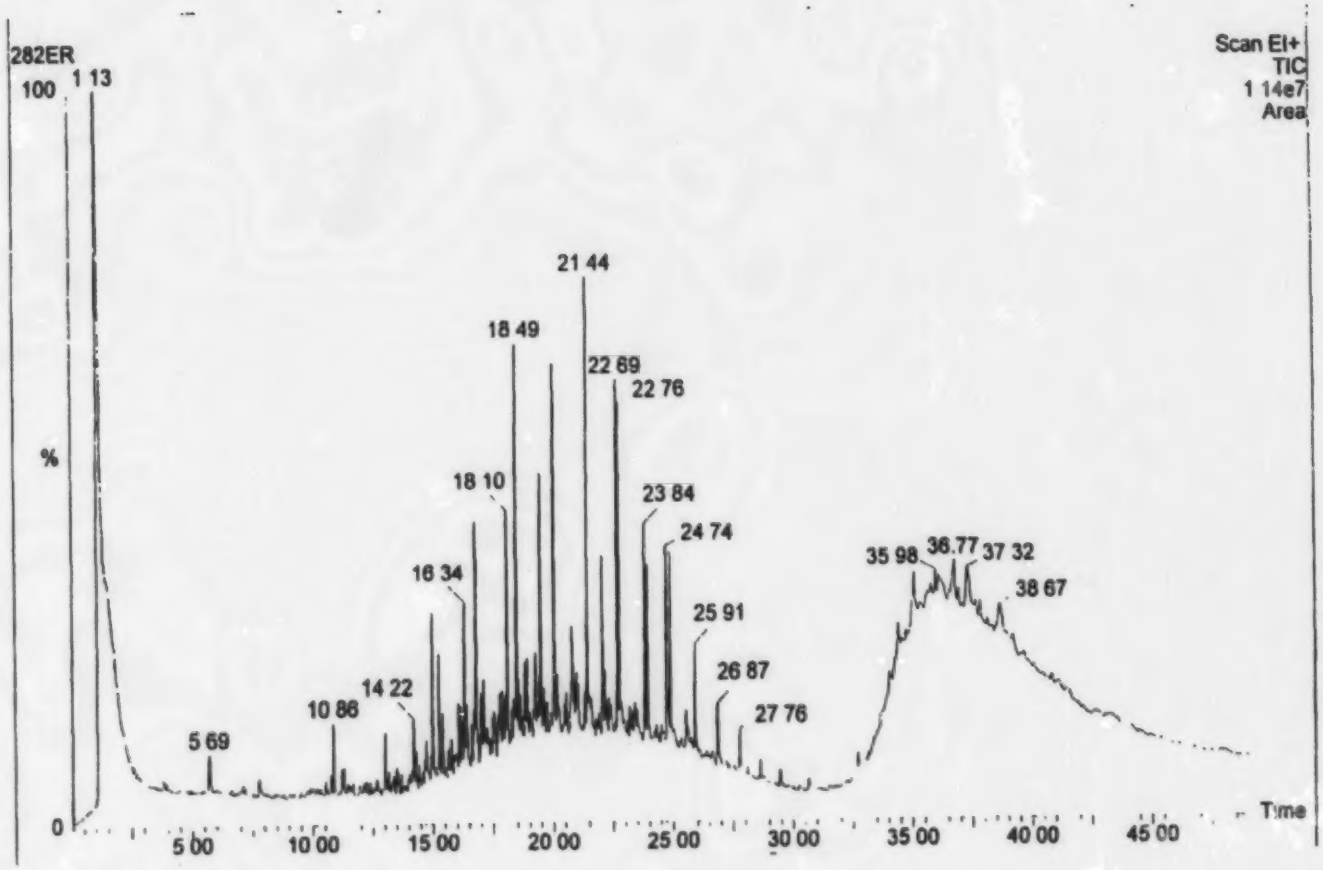


Figure 33 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 282ER. Solid phase microextraction was used to extract the organic constituents.

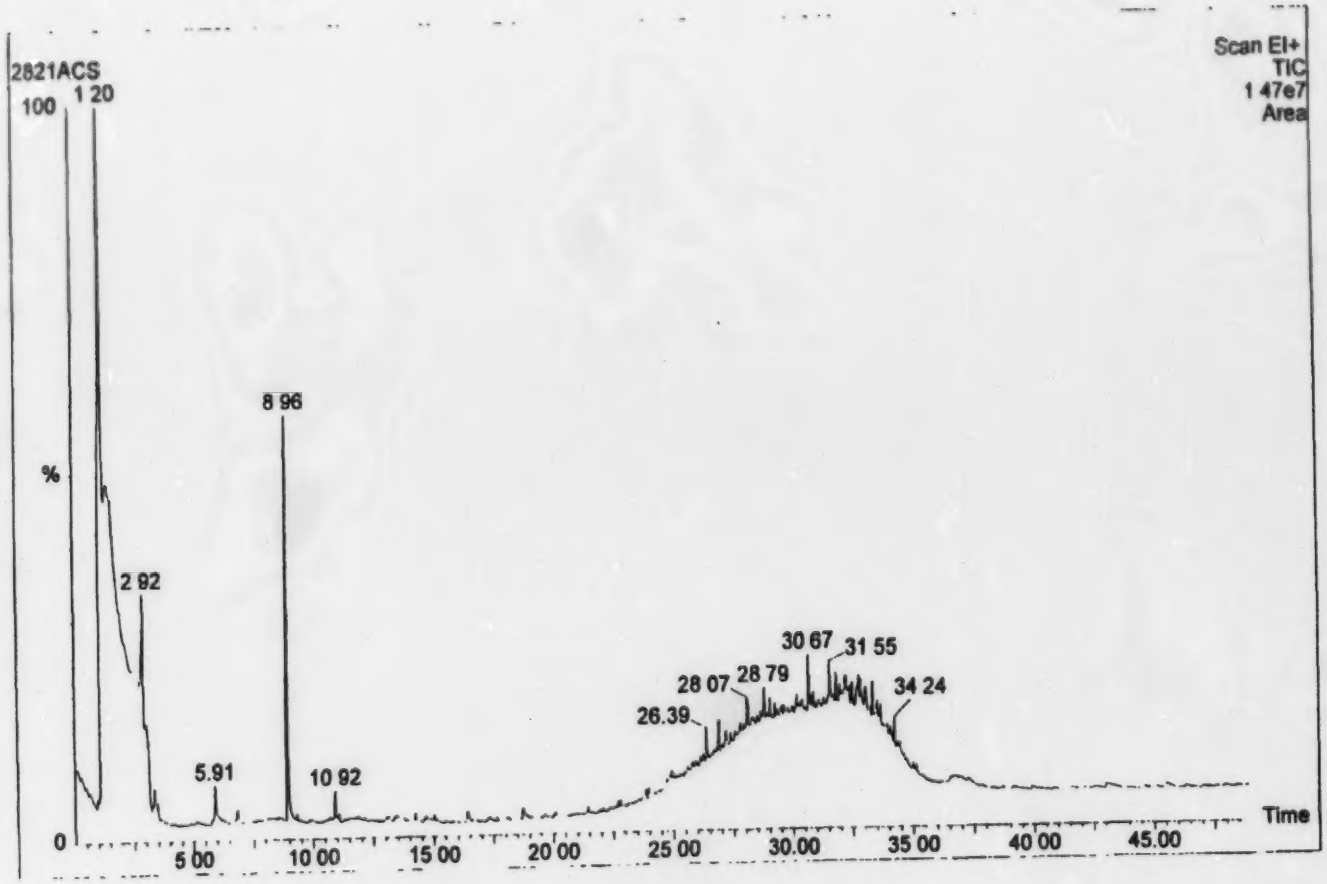


Figure 34 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 282#1ACS. Solid phase microextraction was used to extract the organic constituents.

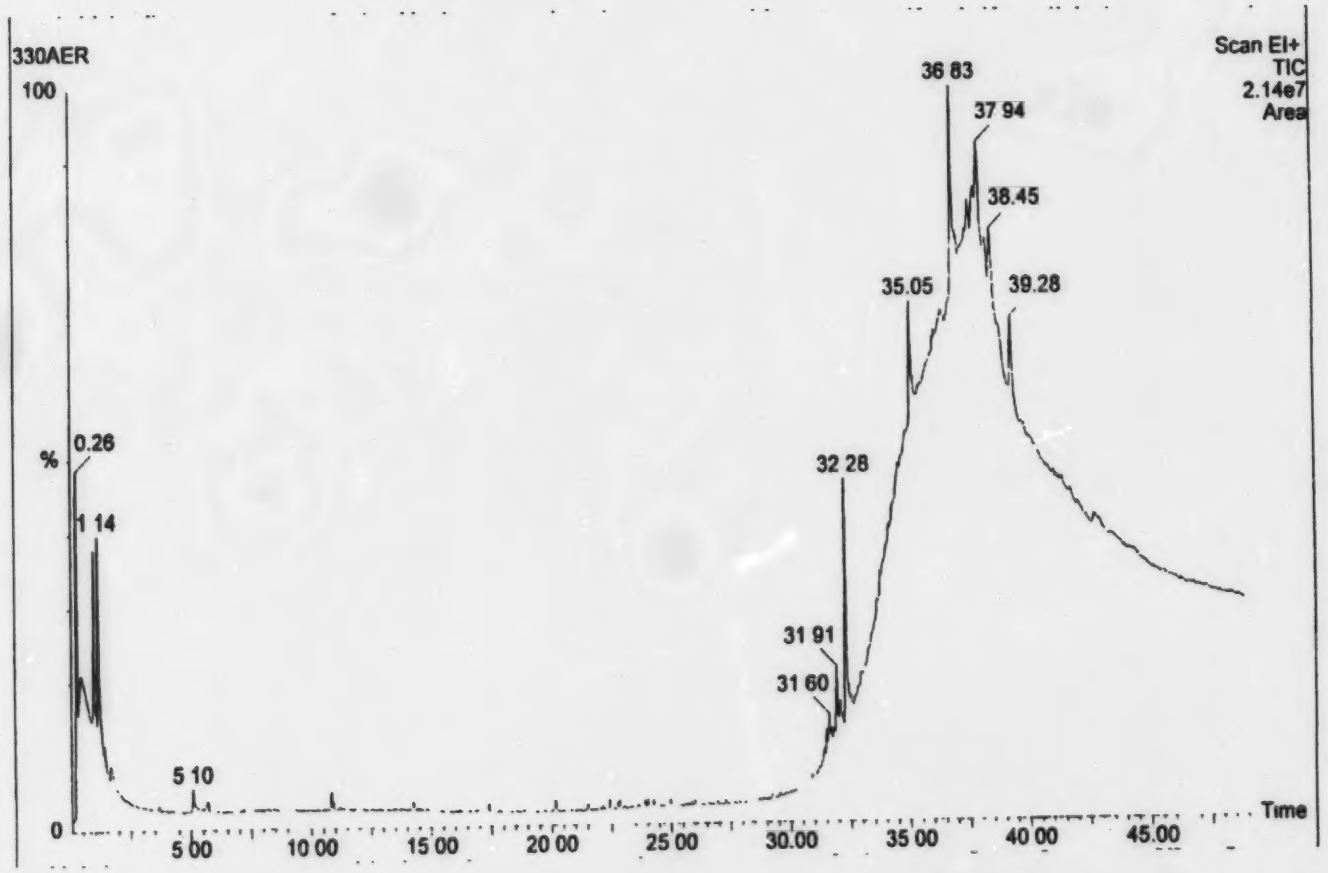


Figure 35 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 330AER. Solid phase microextraction was used to extract the organic constituents.

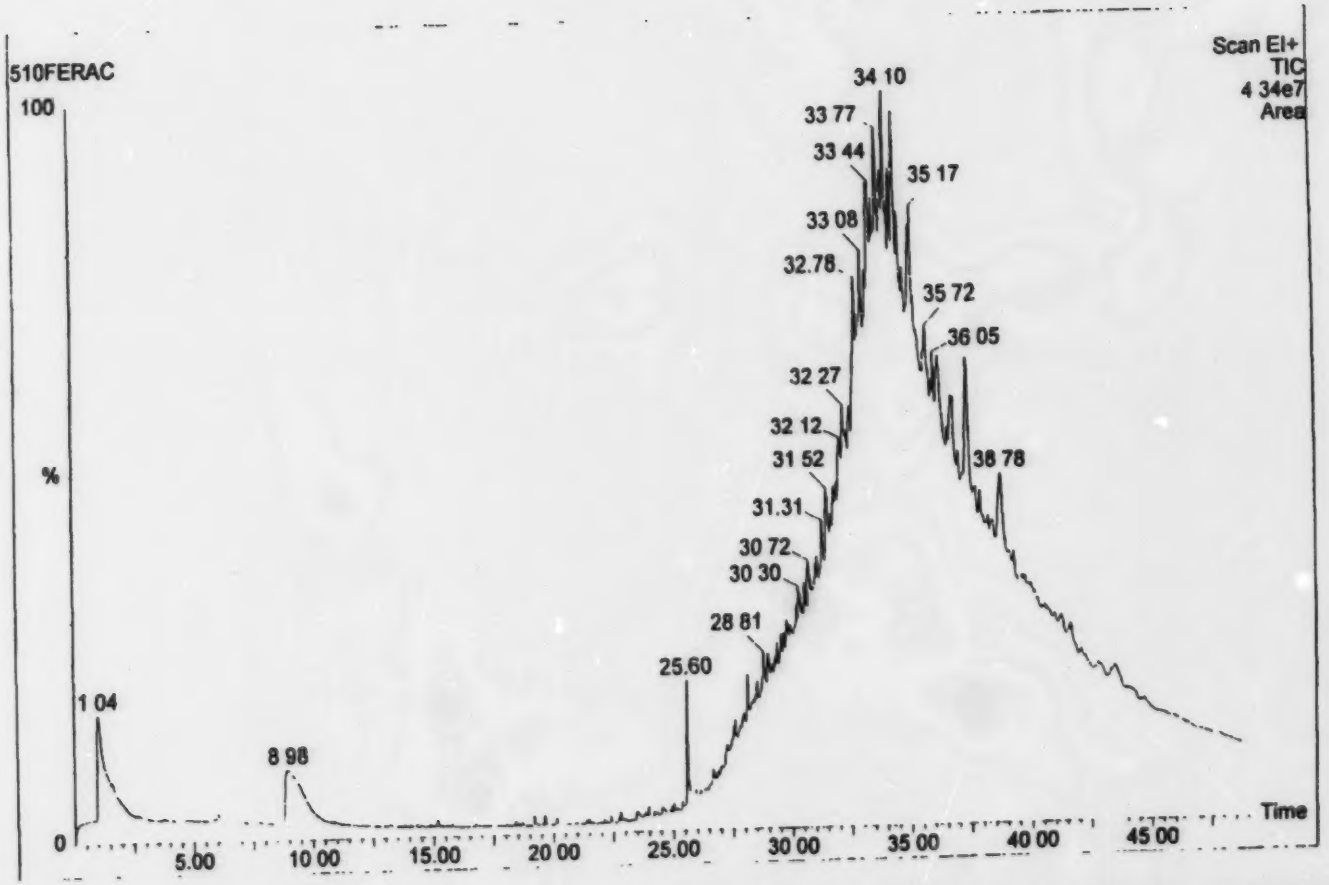


Figure 36 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 510FER(ab). Solid phase microextraction was used to extract the organic constituents.

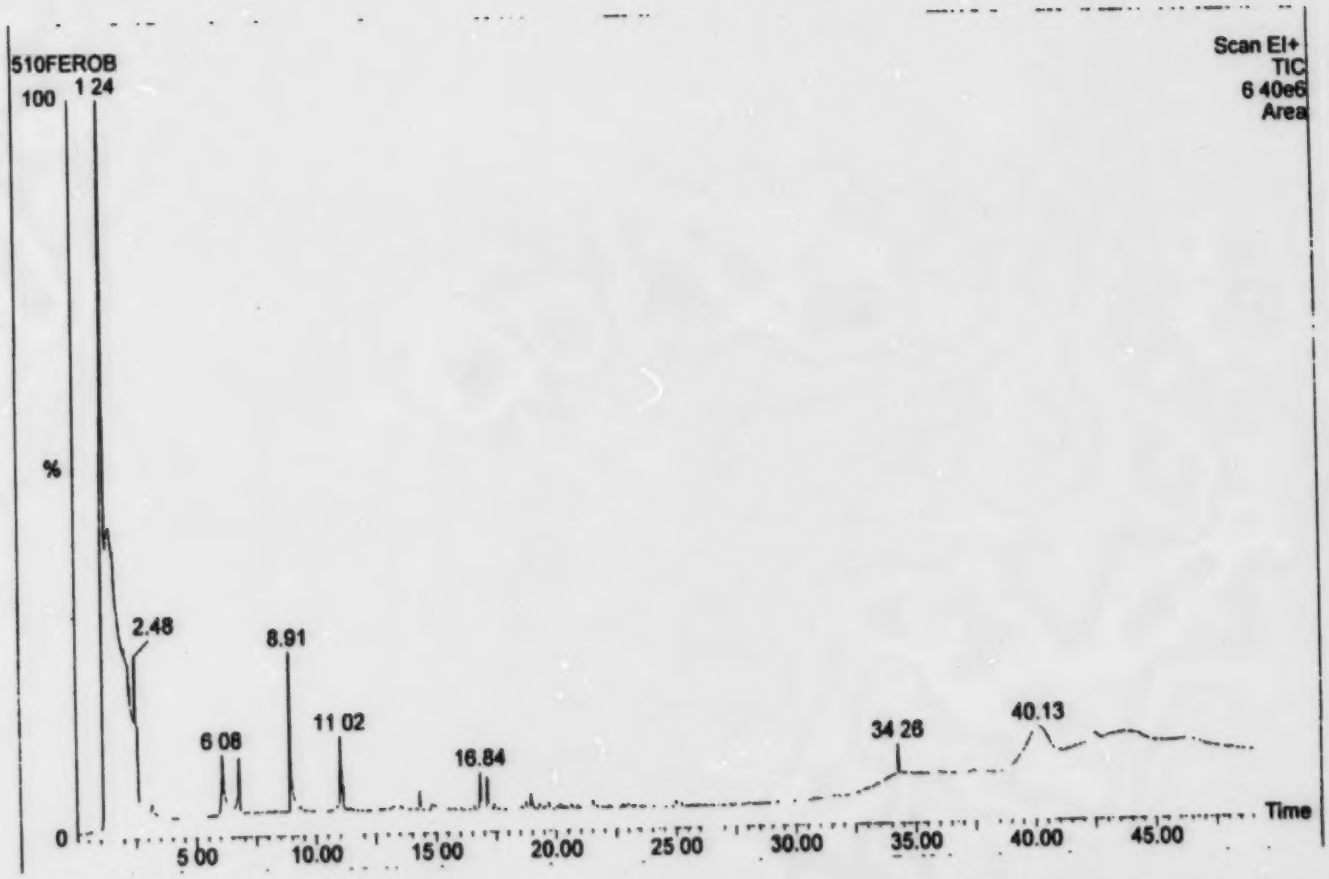


Figure 37 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 510FER(ob). Solid phase microextraction was used to extract the organic constituents.

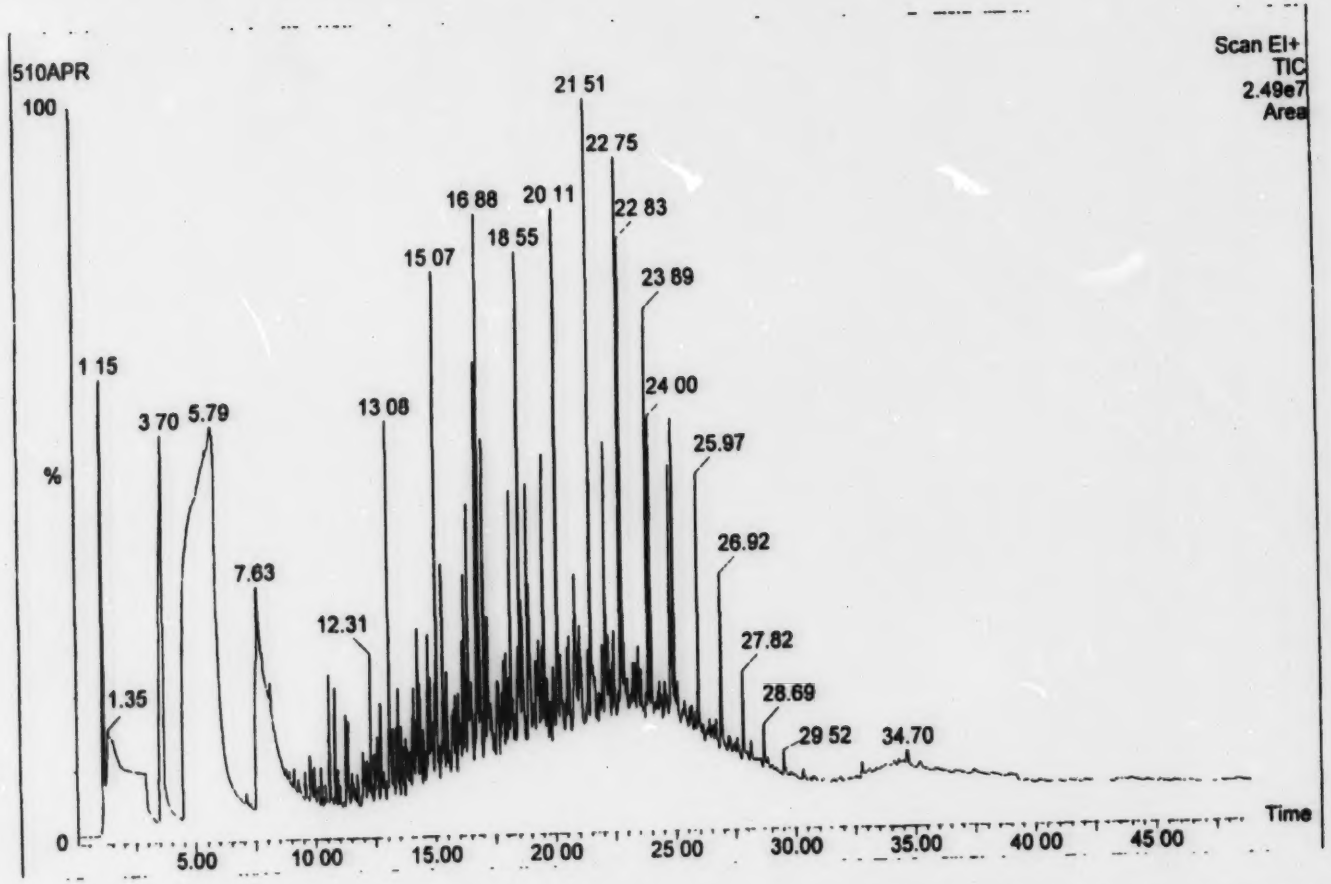


Figure 38 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 510APR. Solid phase microextraction was used to extract the organic constituents.

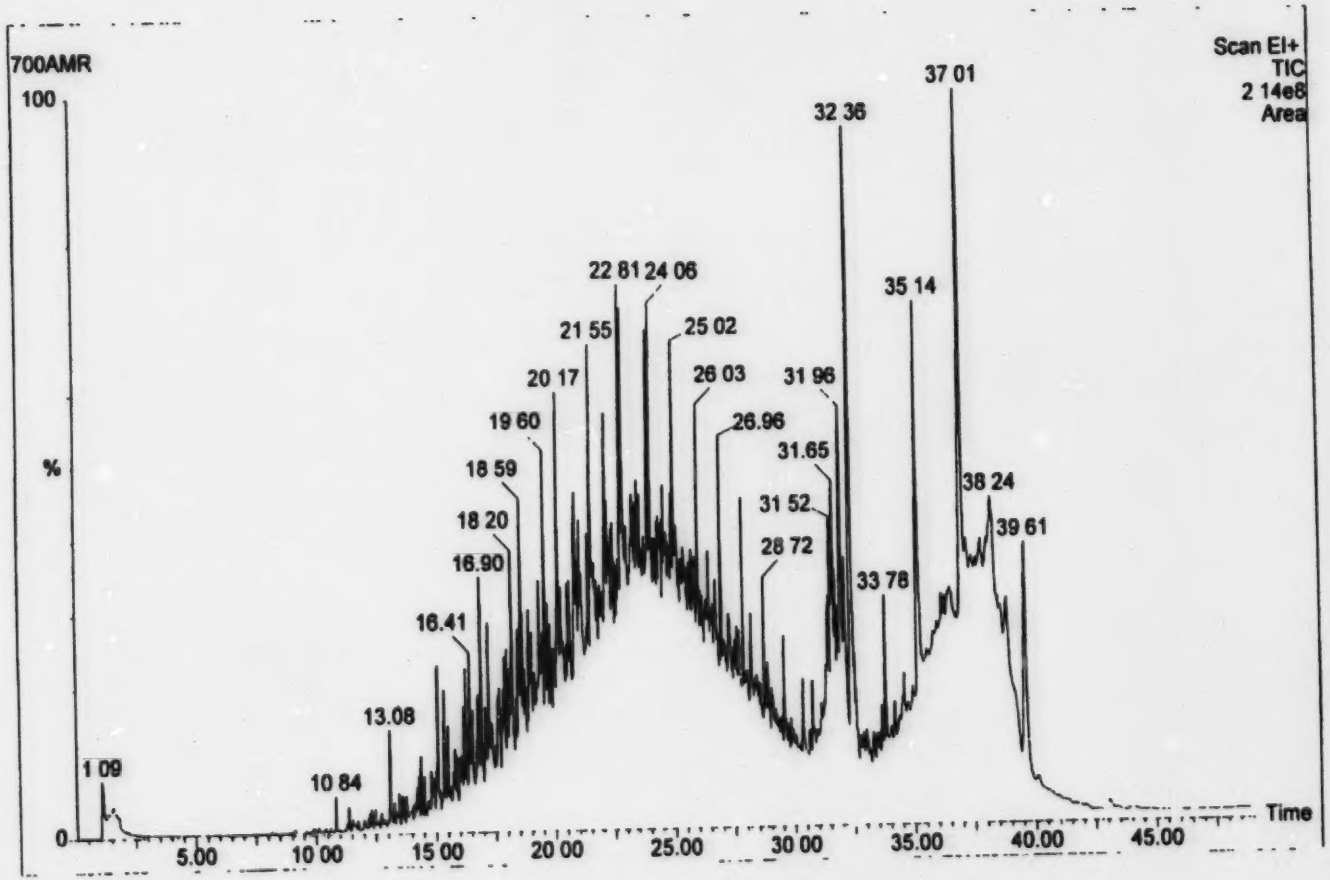


Figure 39 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 700AMR. Solid phase microextraction was used to extract the organic constituents.

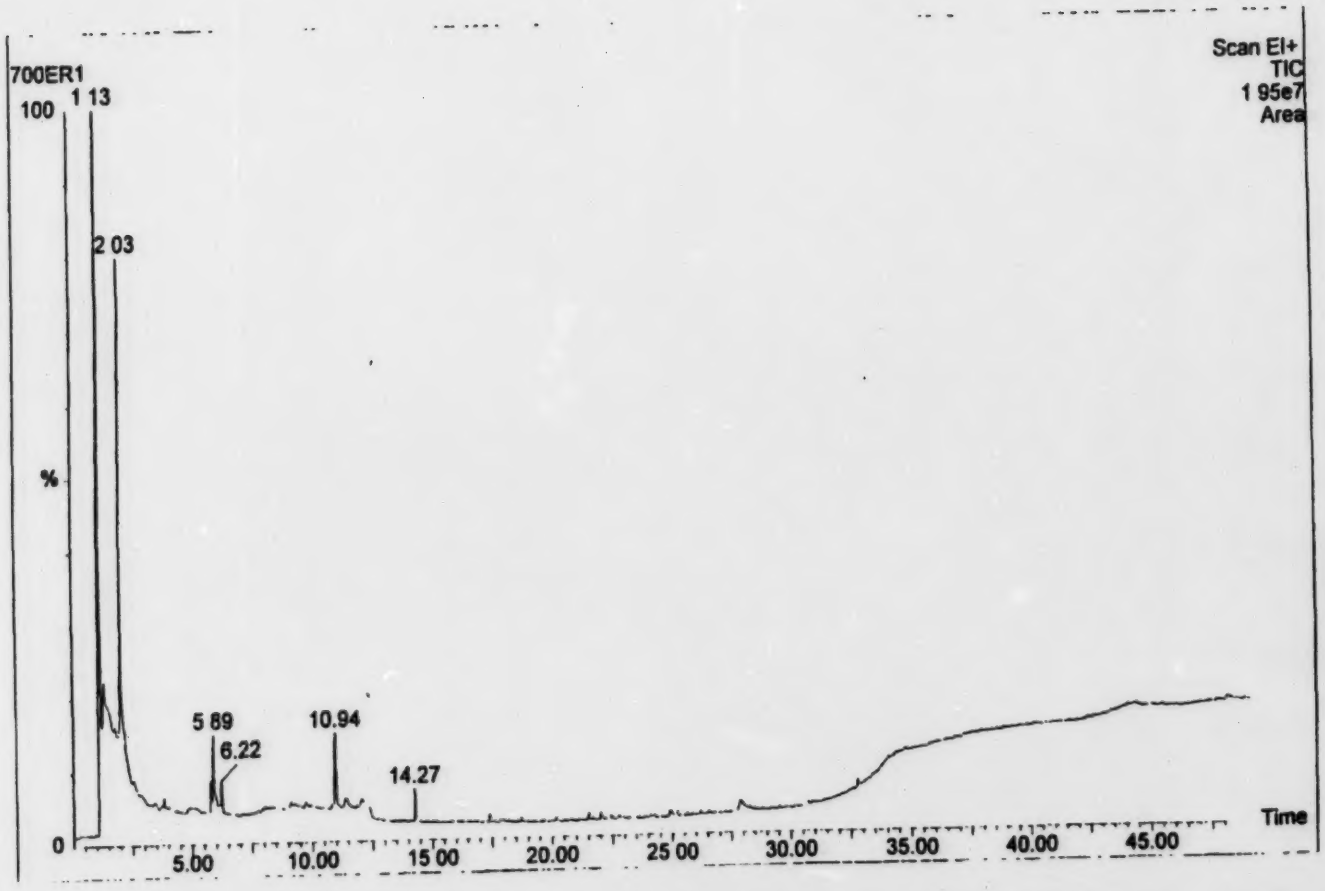


Figure 40 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 700ER. Solid phase microextraction was used to extract the organic constituents.

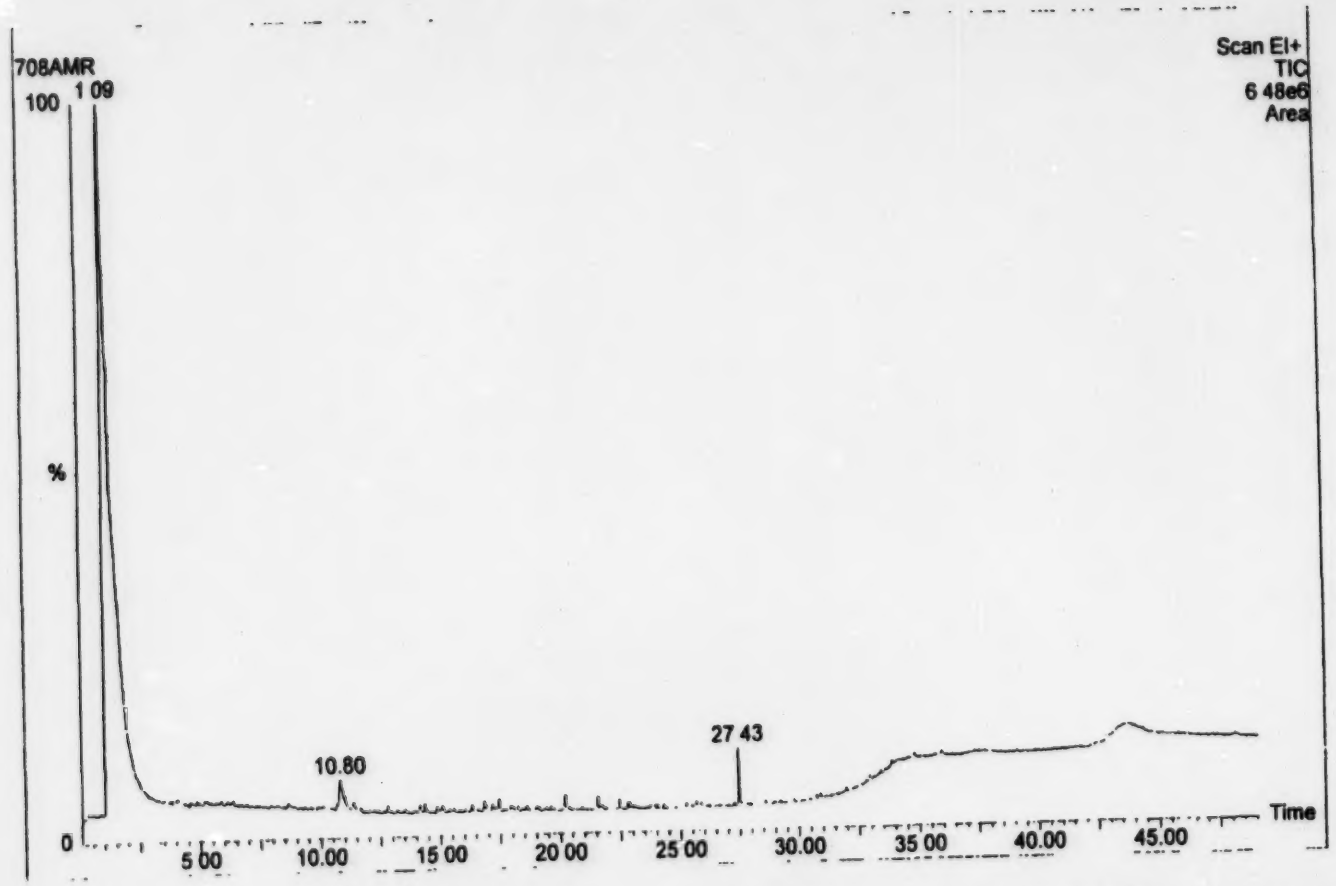


Figure 41 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 708AMR. Solid phase microextraction was used to extract the organic constituents.

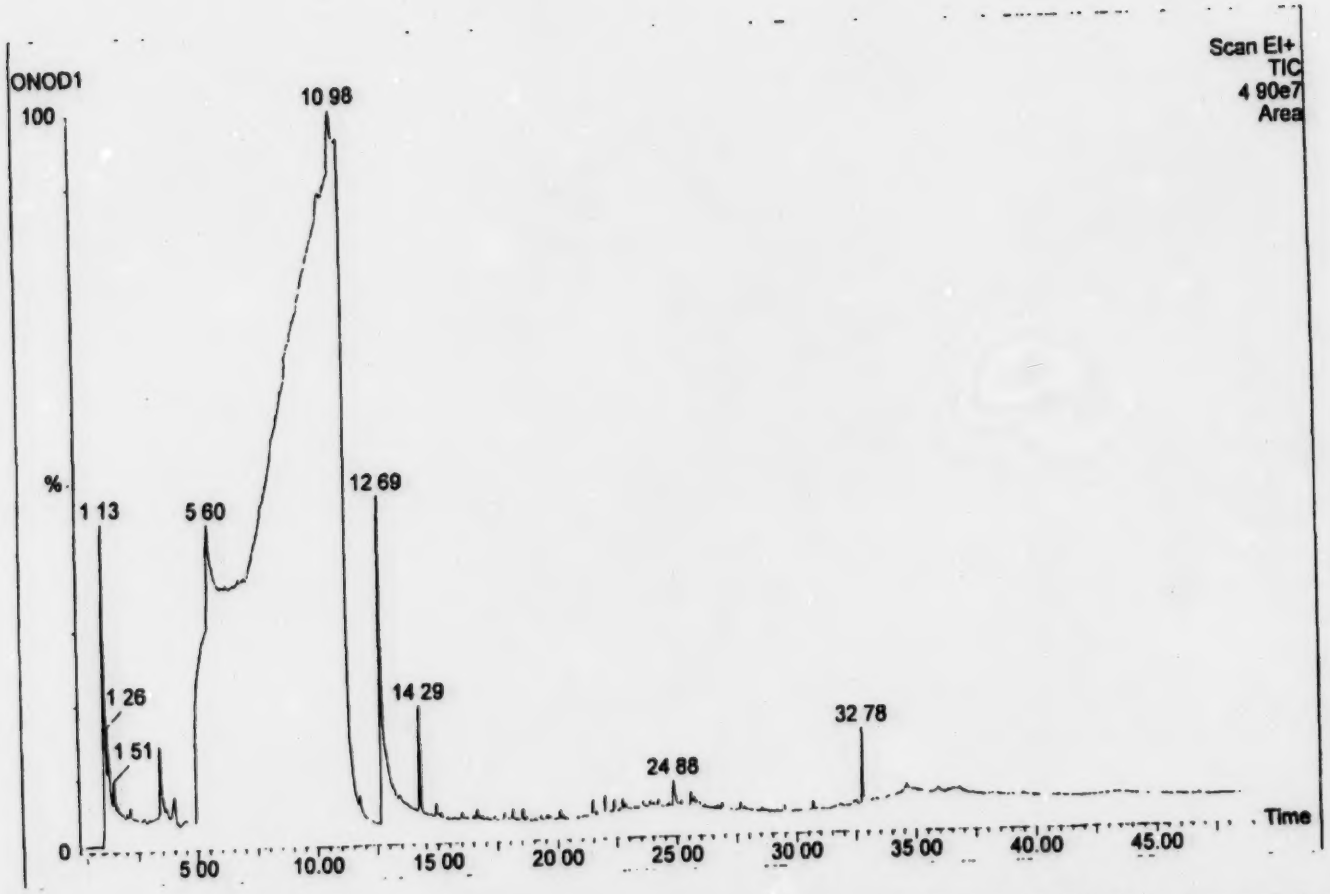


Figure 42 – Chromatogram of the organic constituents in the aqueous layer of bilge sample OnonER. Solid phase microextraction was used to extract the organic constituents.

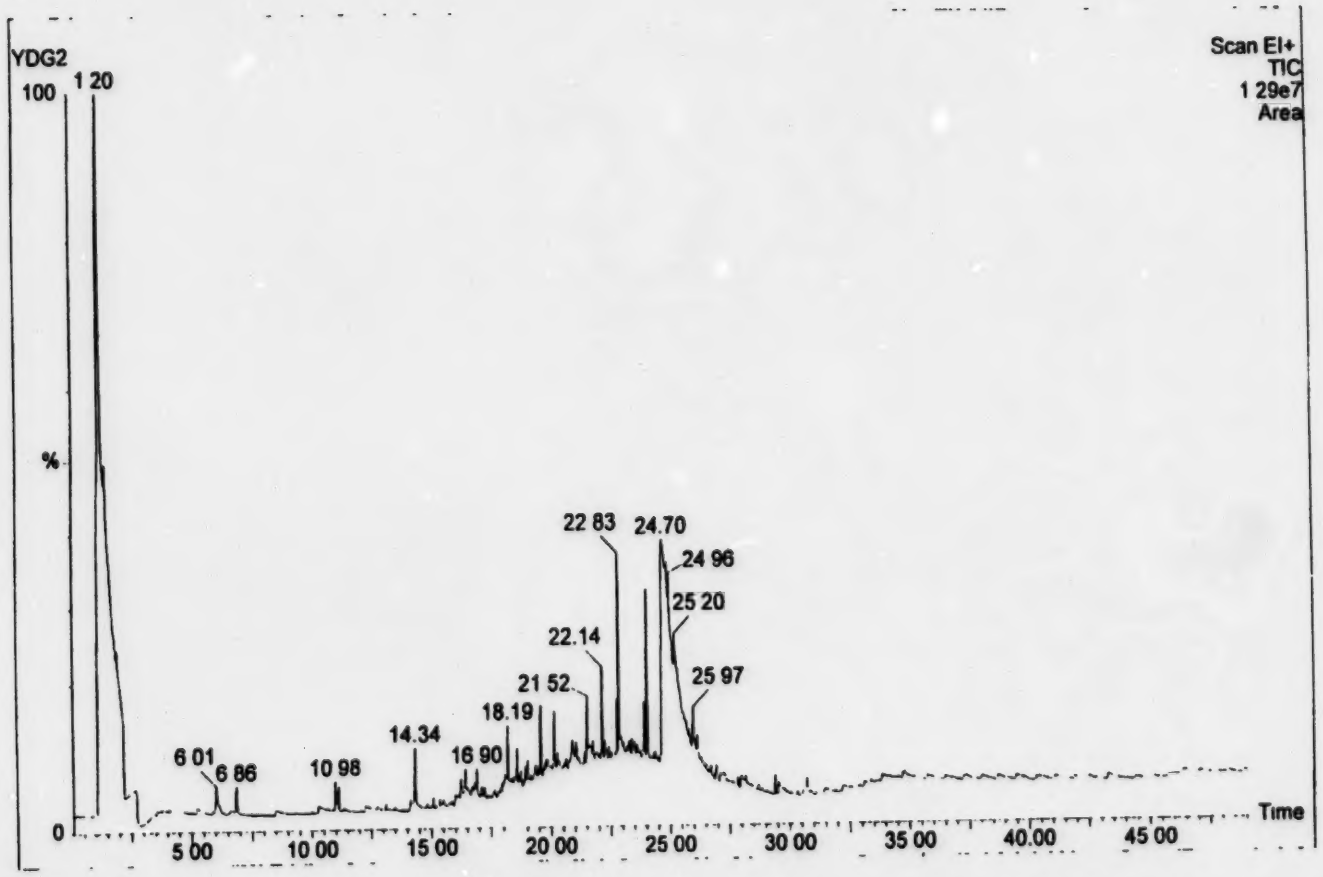


Figure 43 – Chromatogram of the organic constituents in the aqueous layer of bilge sample YDG2. Solid phase microextraction was used to extract the organic constituents.

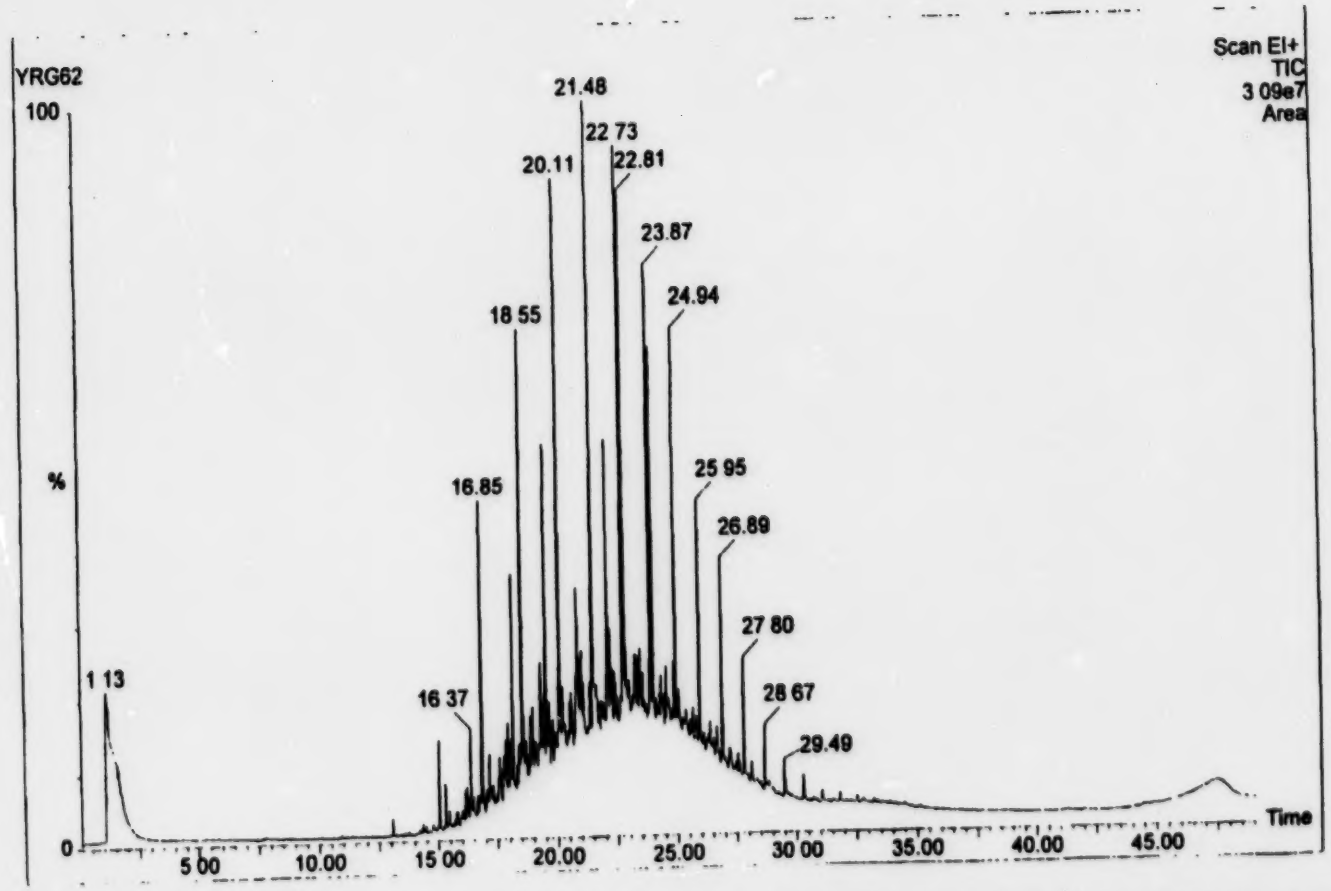


Figure 44 – Chromatogram of the organic constituents in the aqueous layer of bilge sample YRG62. Solid phase microextraction was used to extract the organic constituents.

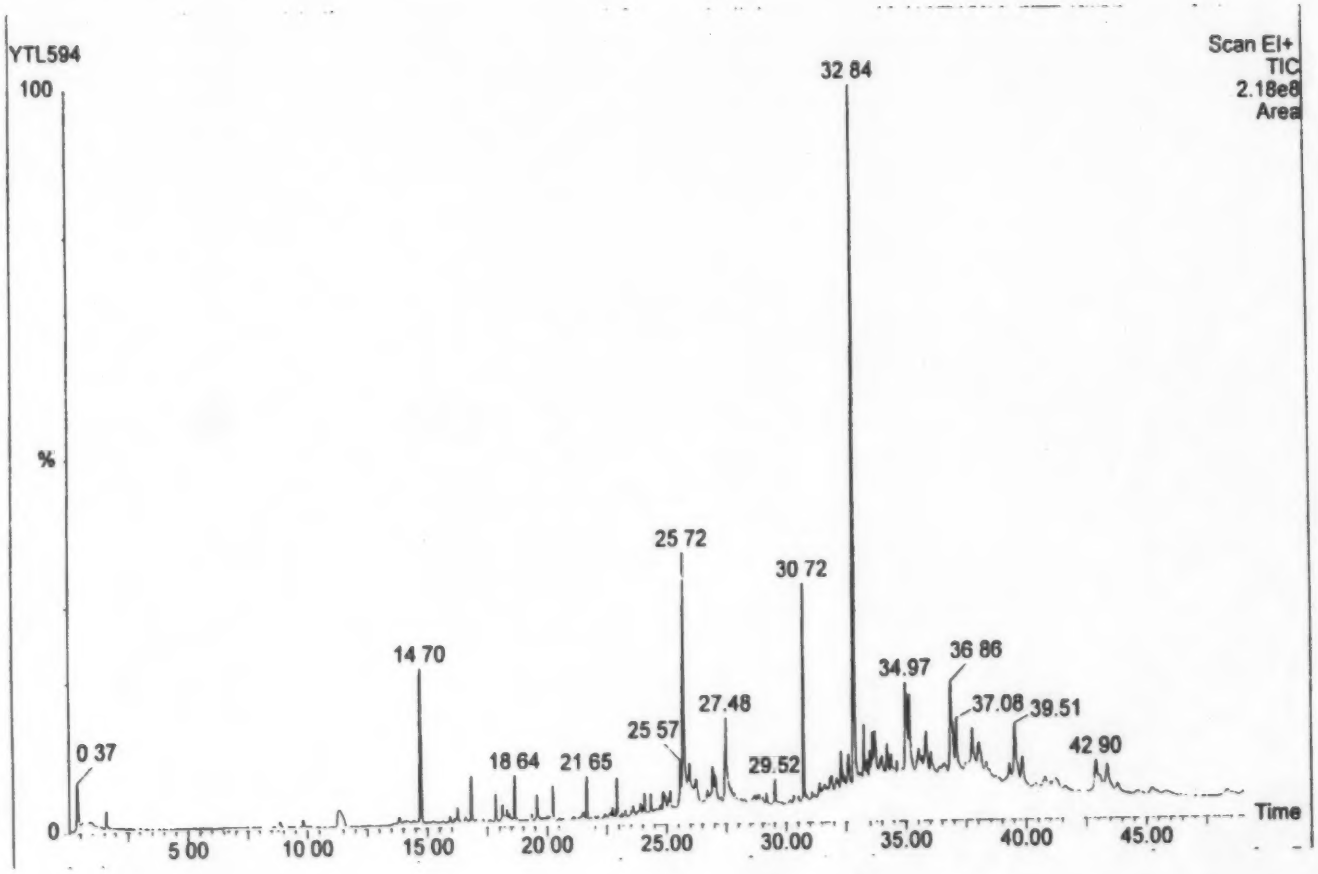


Figure 45 – Chromatogram of the organic constituents in the aqueous layer of bilge sample YTL594. Solid phase microextraction was used to extract the organic constituents.

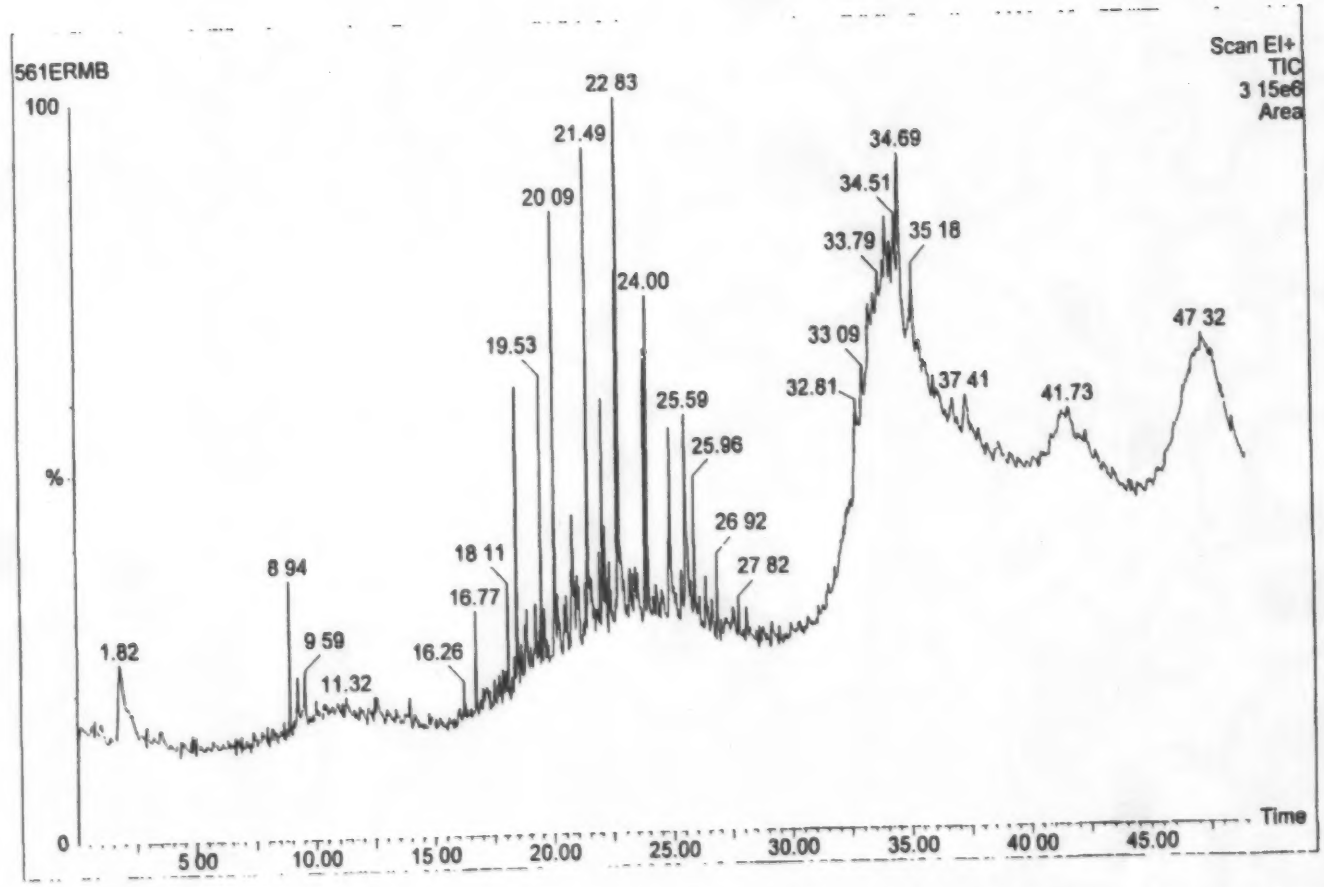


Figure 46 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 561ER. Solid phase microextraction was used to extract the organic constituents.

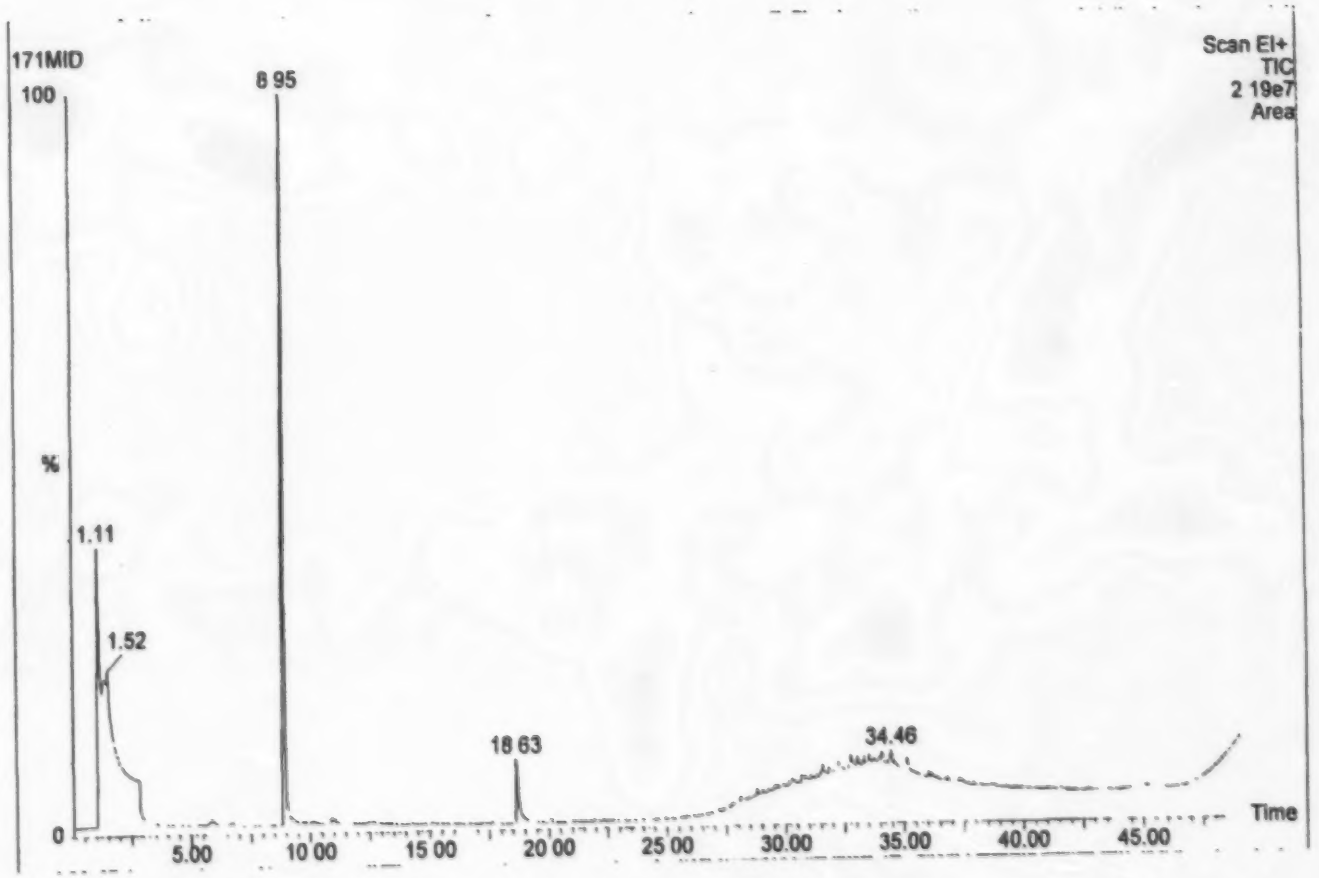


Figure 47 – Chromatogram of the organic constituents in the aqueous layer of bilge sample 171mid. Solid phase microextraction was used to extract the organic constituents.

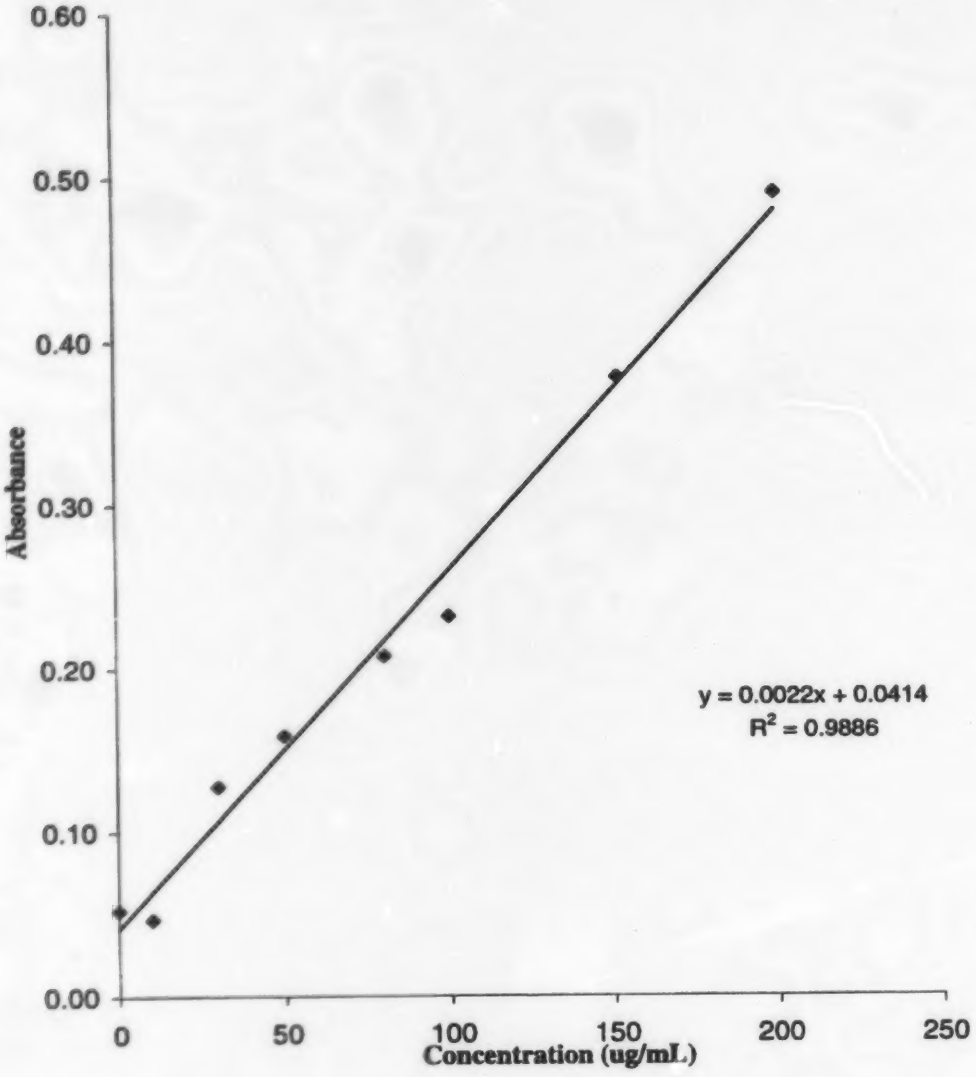
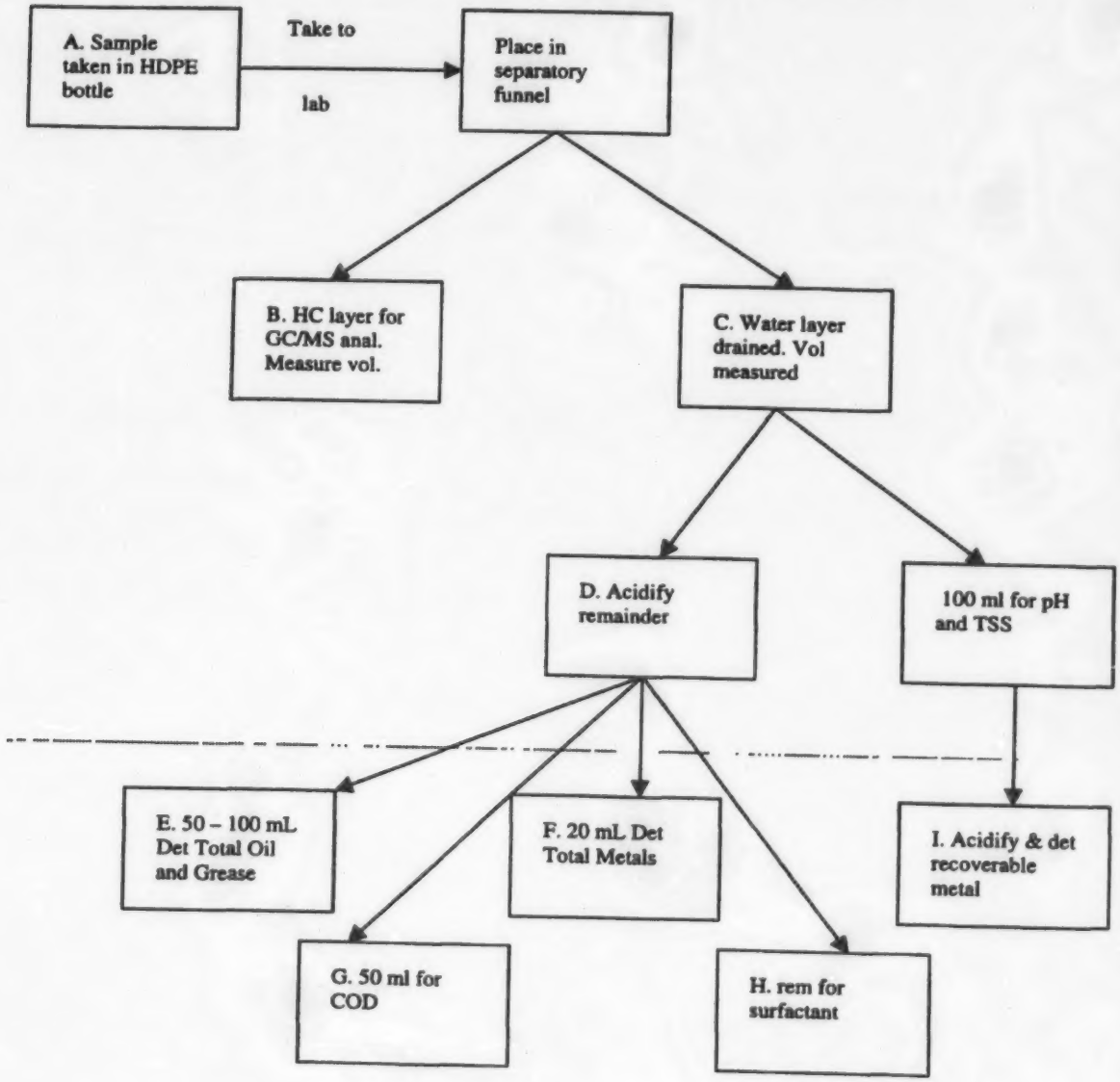


Figure 48. Plot of Concentration of Sodium Salt of Dodecyl-benzene sulfonic acid versus Absorbance

SCHEME 1: ANALYSIS FLOWCHART FOR BILGE WATER SAMPLES


A. Sample taken in HDPE bottle
Take to
lab
Place in separatory funnel
B. HC layer for GC/MS anal. Measure vol.
C. Water layer drained. Vol measured
D. Acidify remainder
100 ml for pH and TSS
E. 50 – 100 mL Det Total Oil and Grease
F. 20 mL Det Total Metals
I. Acidify & det recoverable metal
G. 50 ml for COD
H. rem for surfactant

Appendix 1 - Sample Label Identification

Samples were labelled using an identification system consisting of the Ship Hull Number and an acronym designating the bilge space. For instance, consider the label "330AER". In this label "330" refers to HMCS HALIFAX, while AER refers to after engine room bilge space. A complete description of Ship Hull Numbers and bilge space acronyms is shown below.

HULL NUMBERS

110	HMCS ANTICOSTI
280	HMCS IROQUOIS
282	HMCS ATHABASKAN
330	HMCS HALIFAX
340	HMCS ST.JOHN'S
510	HMCS PRESERVER
700	HMCS KINGSTON
708	HMCS MONCTON
171	CFAV ENDEAVOUR
561	CFAV FIREBIRD
ONON	HMCS ONONDAGA
YDG2	Demagnetism Barge
YTL 594	CFAV PARKSVILLE
YRG62	Wheeler Barge

BILGE SPACE ABBREVIATIONS

AAMR	Aft Auxiliary Machinery Rm
ACS	Air Conditioning Space
Aft.MR	Aft Machinery Room
AMR	Auxiliary Machinery Room
AMS	Auxiliary Machinery Space
APR	Aft Pump Room
ATRp	ATR portside
ATRs	ATR starboard side
BT	Bow Thruster
DS	Dry Stores
ER	Engine Room
ERmi	Engine Room middle
FAMR	Forward Auxiliary Room
FERab	Fwd Engine Rm (aft bilge)
FERmb	Fwd Engine Rm (main bilge)
FERob	Fwd Eng Rm (observation tk)
FPR	Forward pump Room
Fwd.MR	Forward Machinery Room
GR	Gland Room
MoR	Motor Room
OWC	Oily Water Collection Tank
St.C	Steering Compartment
TF	Tiller Flats
ZR	Z Drive Room

Appendix 2 – Wavelength and power settings utilized for determination of dissolved and total metal content by ICP-AES.

ELEMENT	WAVELENGTH (nm)	POWER (kW)
Aluminum	396.152	1.00
Calcium	370.603	1.00
Cadmium	228.802	1.50
Chromium	267.716	1.50
Copper	324.754	1.00
Iron	259.940	1.50
Lead	405.783	1.00
Magnesium	285.213	1.00
Manganese	257.610	1.50
Nickel	231.604	1.50
Potassium	766.490	1.00
Silicon	212.412	1.00
Sodium	588.995	1.00
Tin	189.926	1.00
Titanium	368.520	1.00
Zinc	213.856	1.50

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4 AUTHORS (Last name, first name, middle initial If military, show rank, e.g. Doe, Maj. John E.)

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The results of the characterization of 40 bilge samples from CF ships are reported. The characterization included analysis of the pH, dissolved metal content, total suspended solids and total oil and grease in the aqueous phase and identification of the major components of the organic phase of the bilge samples. Eight samples exceeded the limit for dissolved cadmium and nine samples exceeded the limit for dissolved zinc. Five samples exceeded the limit for total suspended solids. The major components of the organic phase of the bilge samples were 3-GP-11 naval distillate fuel and lubricating oils. Five samples, that showed evidence of emulsification, were analysed for surfactants. All samples contained less than 30 parts per million anionic surfactant.

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Bilge water analysis, bilge water characterization

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